Incorporating Water Resources Impacts in Integrated Assessment Models

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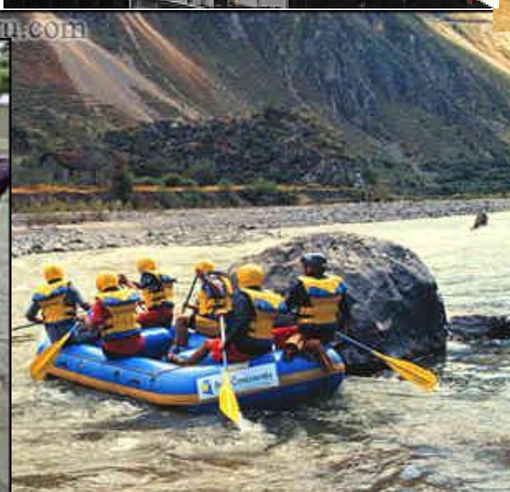
AP

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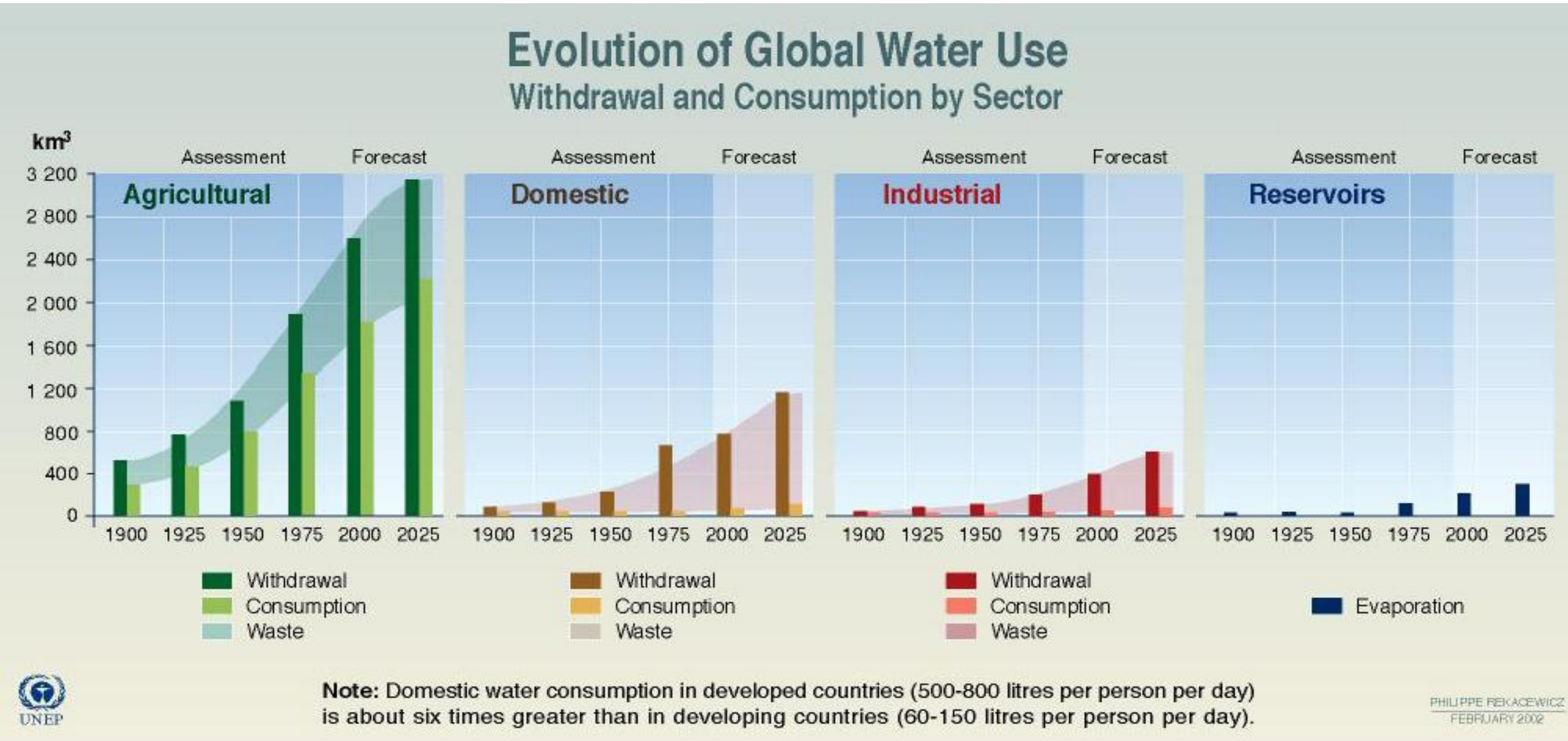
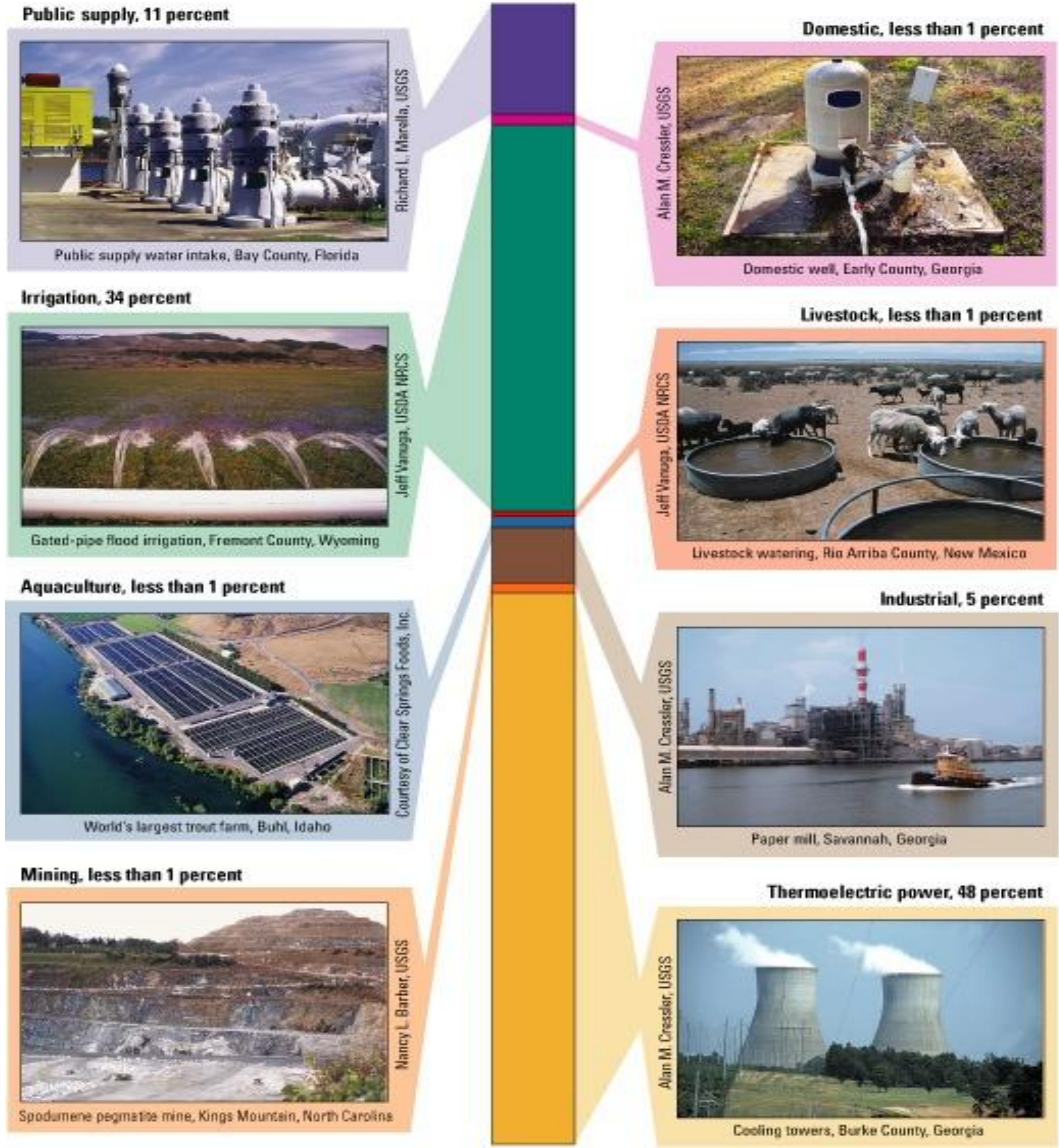
Elements of the Water System

- The Hydrologic System
  - Climate and Land Use
- The Managed Water Supply System
- Water Demand
  - Aquatic Ecosystem
  - Market Activities
  - Human Health
  - Non-Market Activities
- Excess Water
- Role in Economic Development

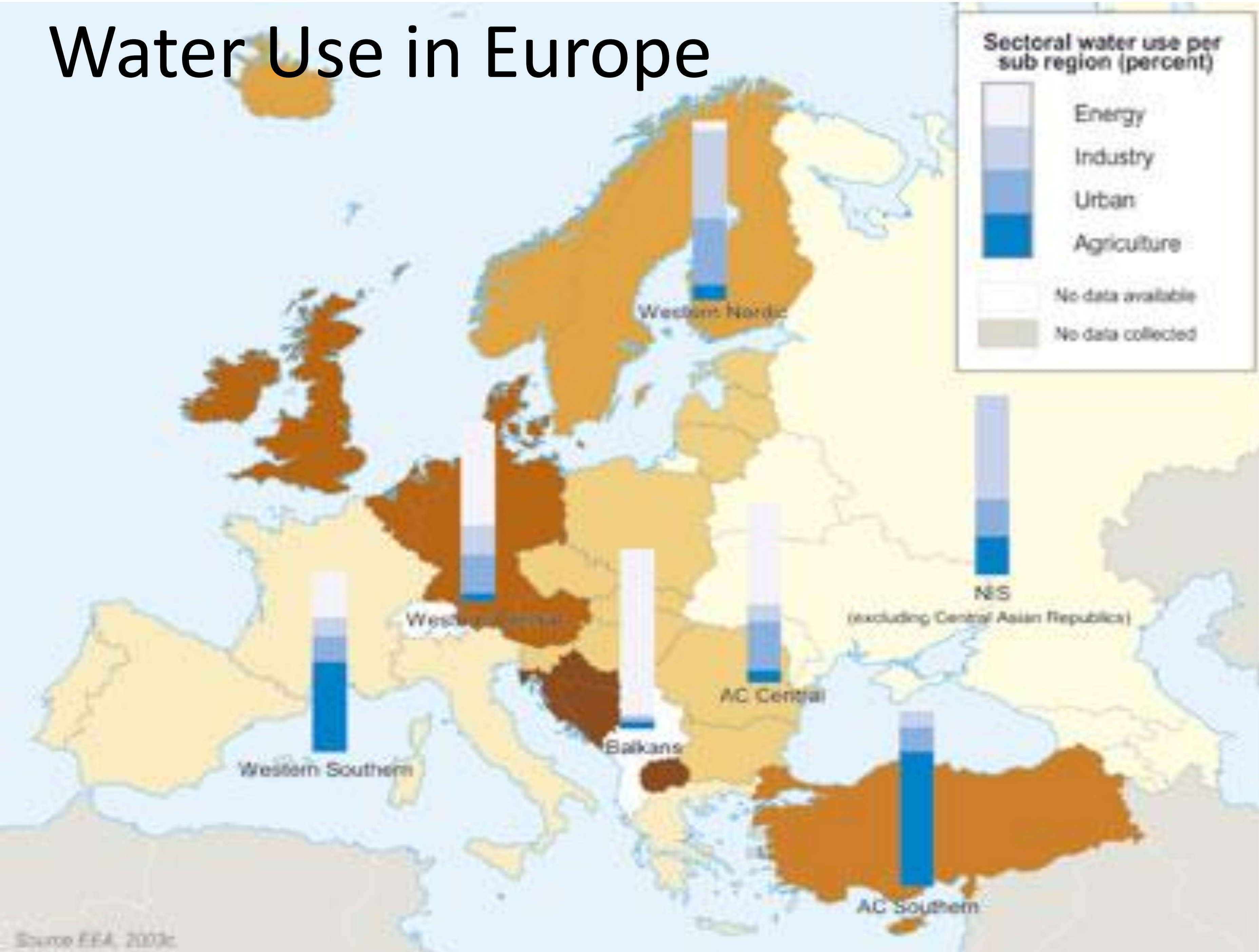


Source: Igor A. Shiklomanov, State Hydrological Institute (SHI, St. Petersburg) and United Nations Educational,Scientific and Cultural Organisation (UNESCO, Paris), 1999.

United States Water Use 2005



Water Use in Europe



Modeling Water Resources Impacts in IAMS

- **We know how to model key water related at the River Basin Level**

Hydrology, Crops, Energy, M&I, ….

Combined Use of Optimization and Simulation Models in River Basin Planning

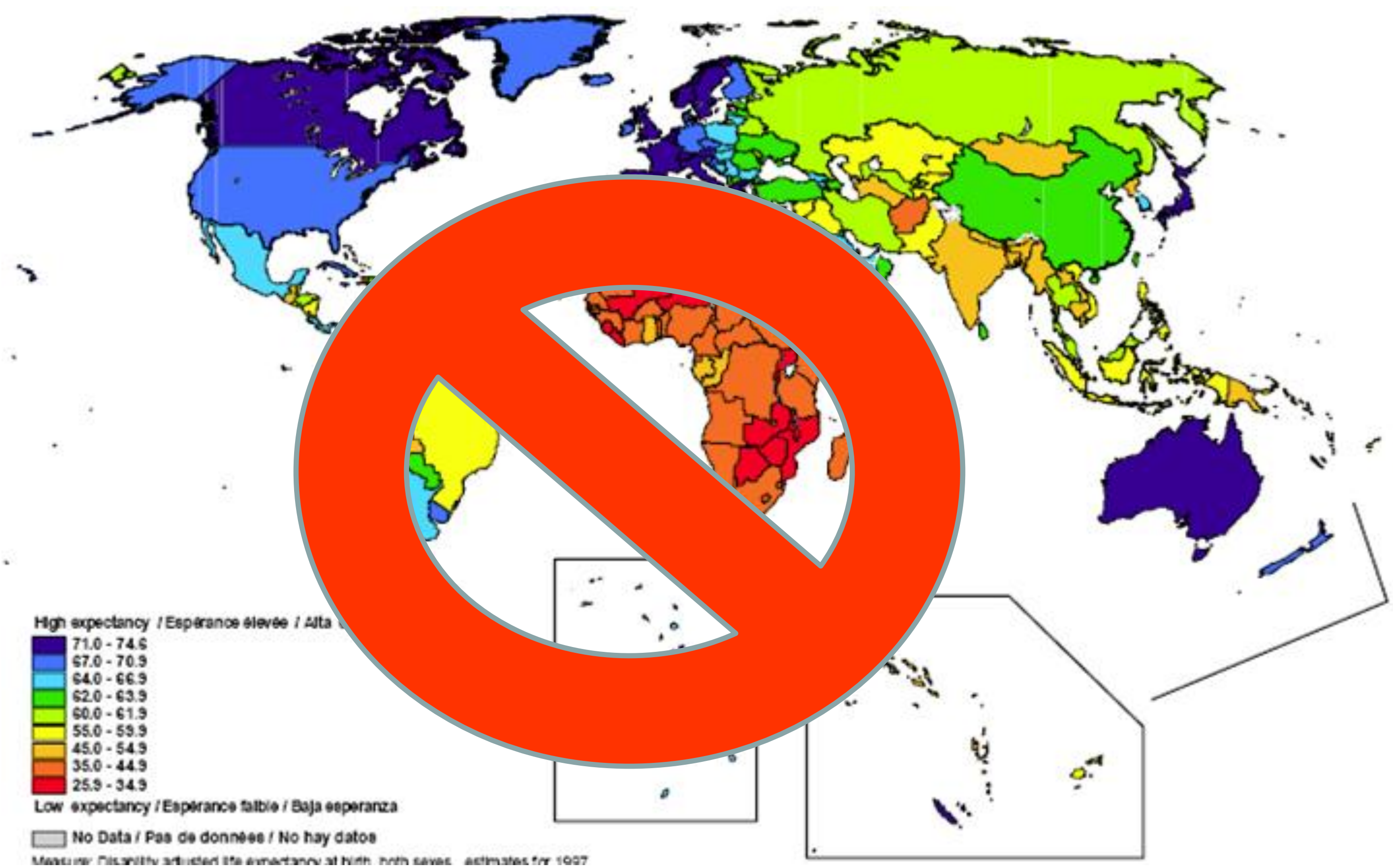
Henry D. Jacoby & D. P. Loucks *WATER RESOURCES RESEARCH, VOL. 8, NO. 6,, 1972*

- What is the appropriate Spatial and Temporal Scale to accurately model climate change impacts for the questions being asked by IAMs or sectoral level analysis at what scale.
- IAMs
  – Spatial Scale: 10 to 20 regions: National lowest Scale
  – Temporal Scale: 1 to 5 year time steps
- Global Crop and Hydrologic Modeling at 0.1 to 0.5 degree dail
- There are over 10,000 level 4 River Basin "~20,000 km2"
- Water Mgt Models : "River Basin Scale" and Monthly

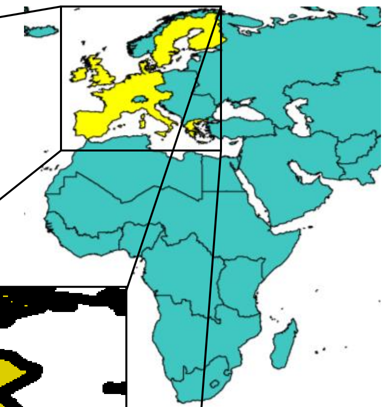
Spatial Scale Economic Components of Selected IAMs

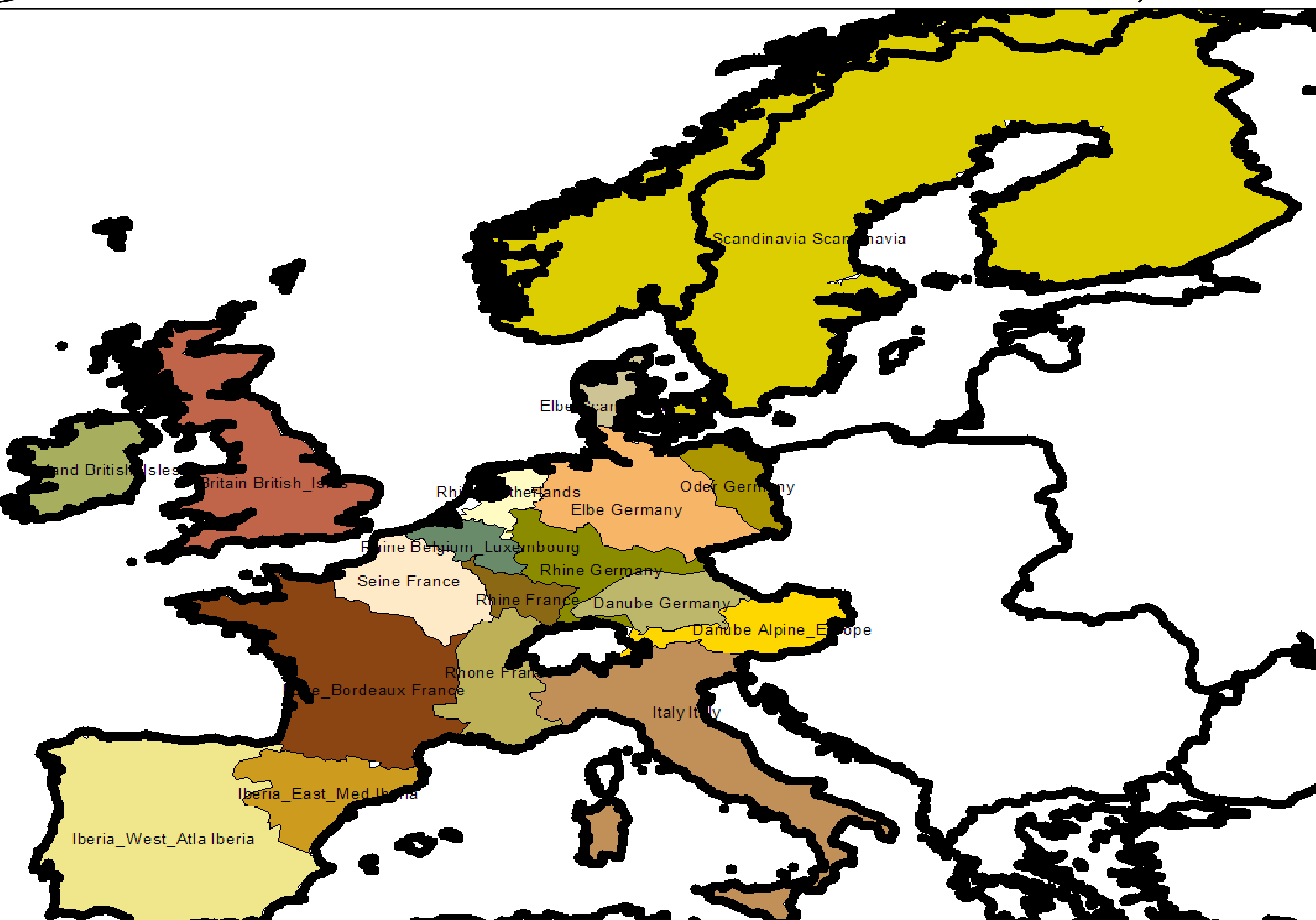
- MiniCAM: 14 Regions
  - the United States, US, Canada, W. Europe, Australia & New Zealand, Japan, Eastern Europe, The Former Soviet Union, China, Mid-East, Africa, Latin America, Korea, Southeast Asia, and India. In addition, three others are under development: Mexico, Argentina, and Brazil.
- MERGE: 9 Regions
  - Canada, Australia and New Zealand (CANZ); China; eastern Europe and the former Soviet Union (EEFSU); India; Japan; Mexico, and OPEC (MOPEC); western Europe (WEUR); the United States of America (USA); and the rest of the world (ROW).
- IGSM/EPPA: 16 Regions
  - United States (USA) European Union (EUR) Eastern Europe (EET) Japan (JPN) Former Soviet Union (FSU) Australia & New Zealand (ANZ) Canada (CAN China (CHN) India (IND) Higher Income East Asiad(ASI) Middle East (MES) Indonesia (IDZ) Mexico (MEX) Central & South America (LAM) Africa (AFR) Rest of World (ROW)
- Fund : National Level

Global Water and AG IMPACTS Regional and National Scale

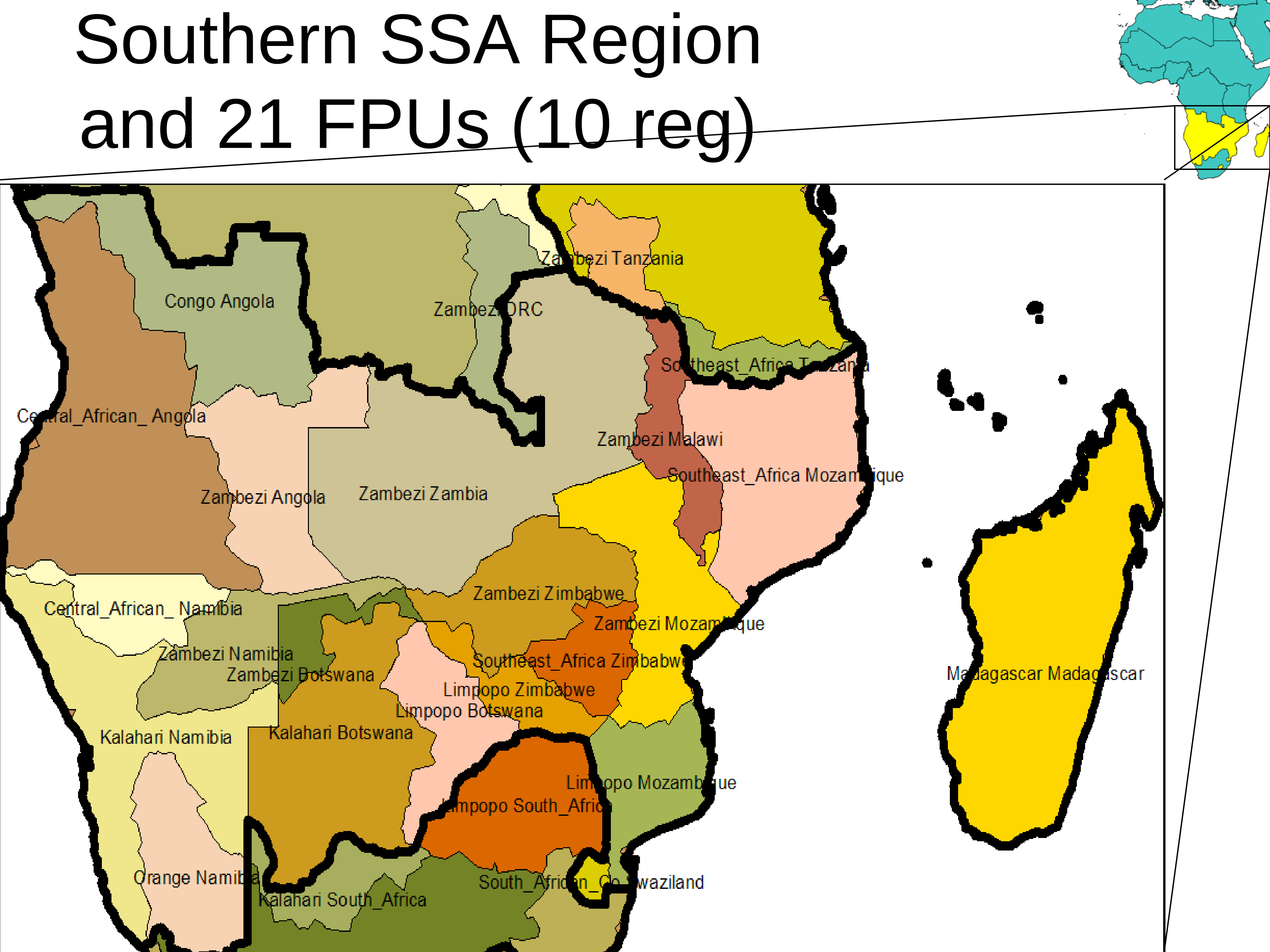


Europe Region and 18 FPUs (9 reg)

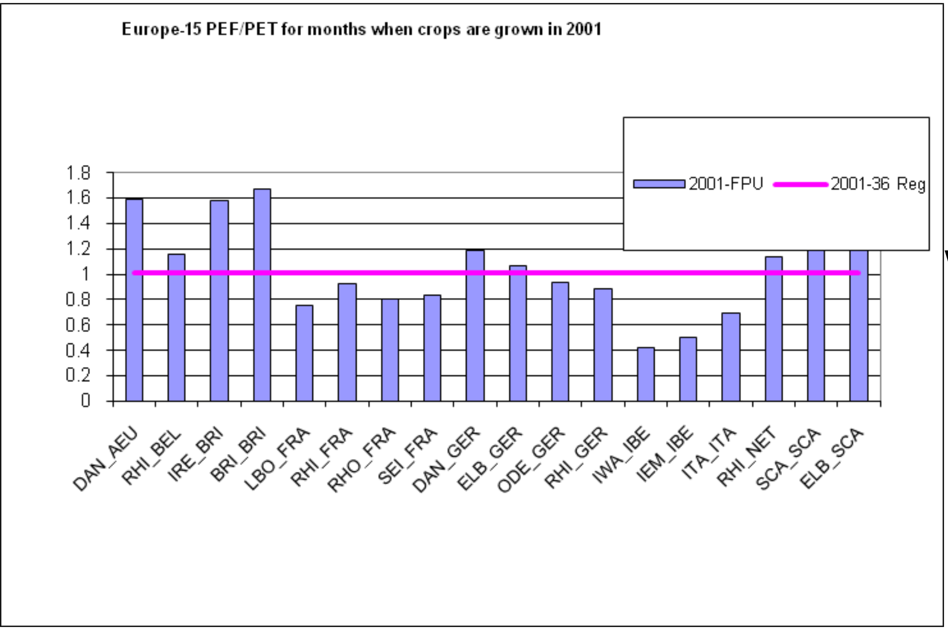




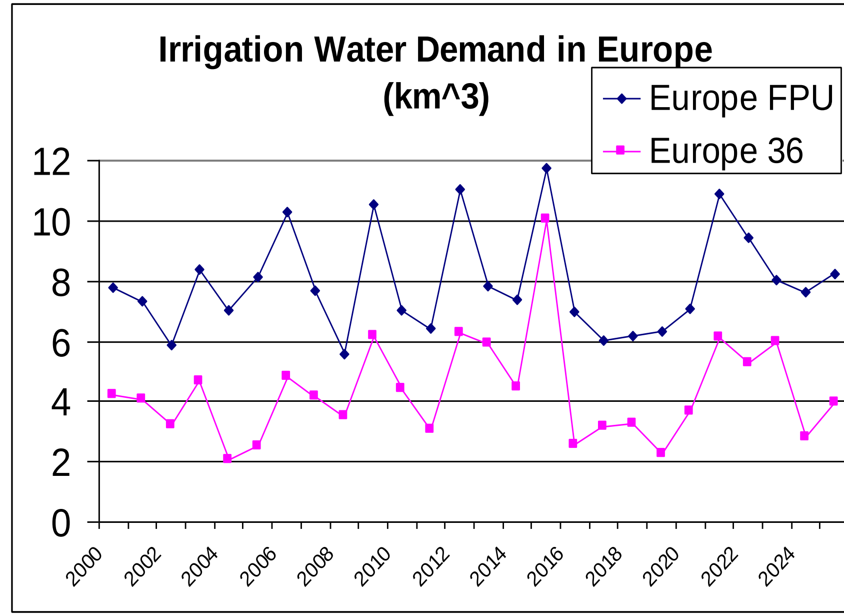
Southern SSA Region and 21 FPUs (10 reg)

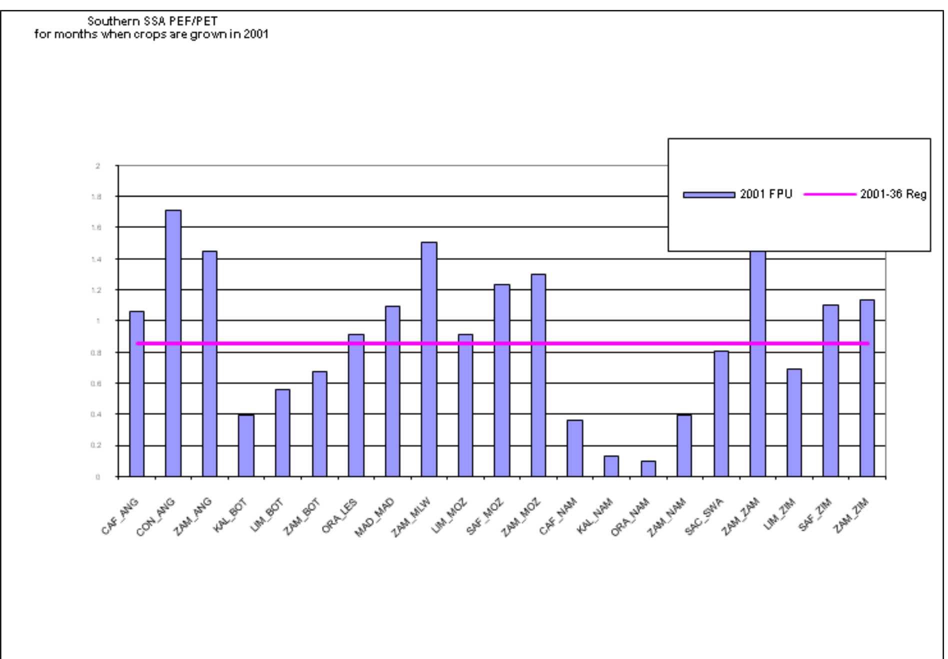


Irrigation Water Demand

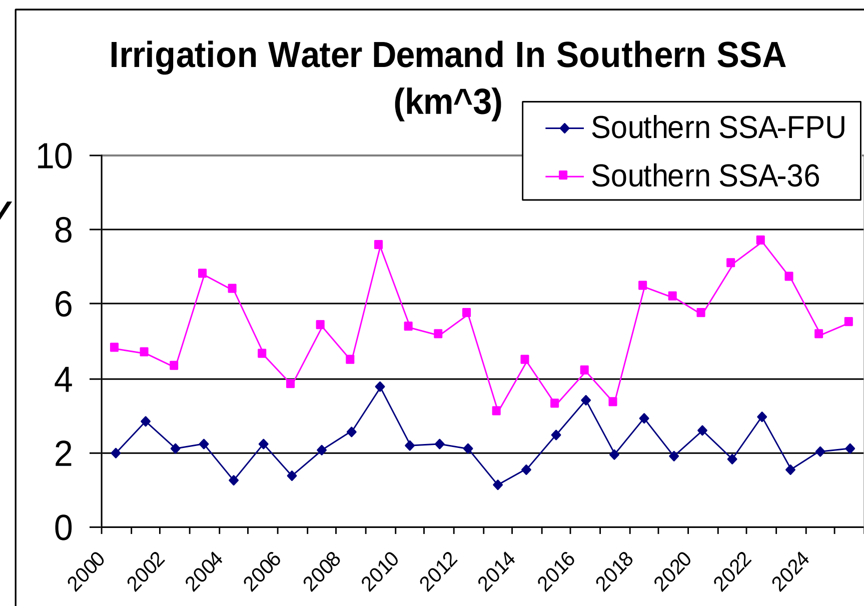


WET

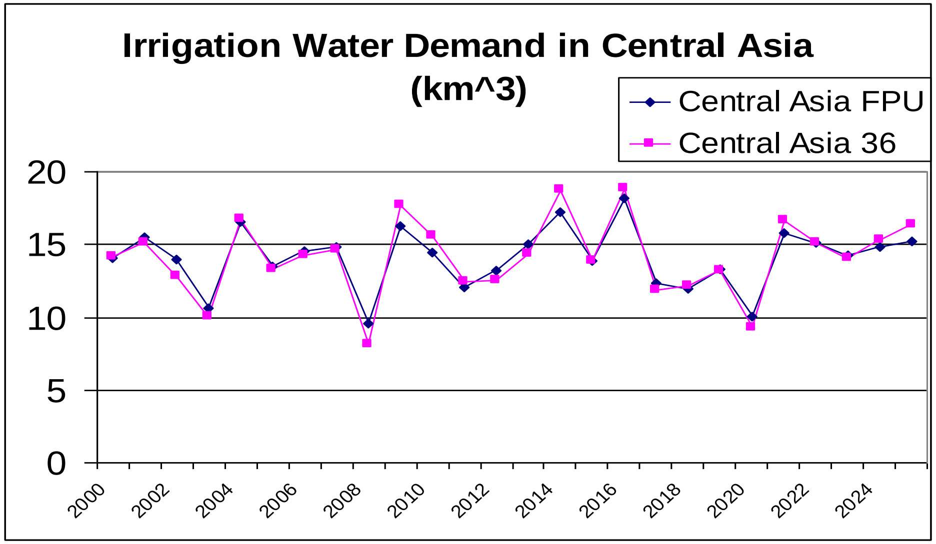


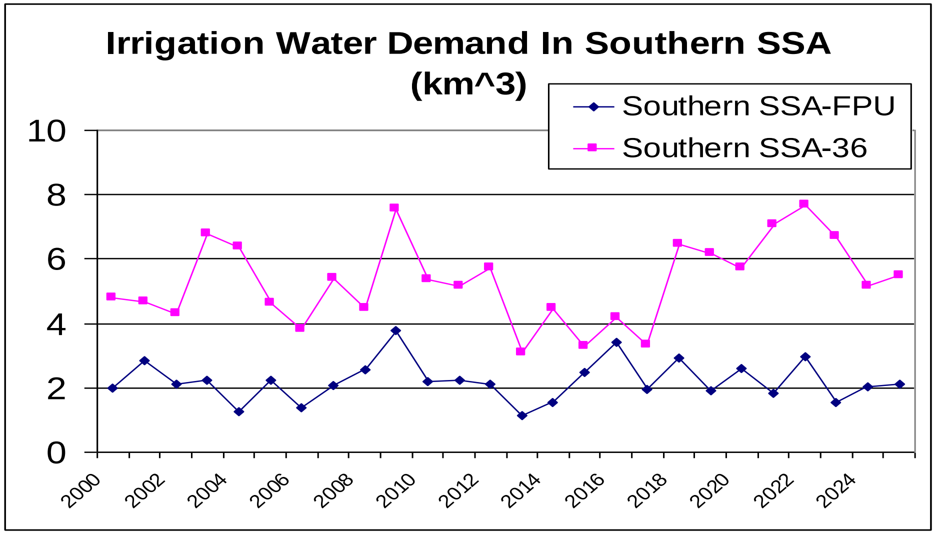


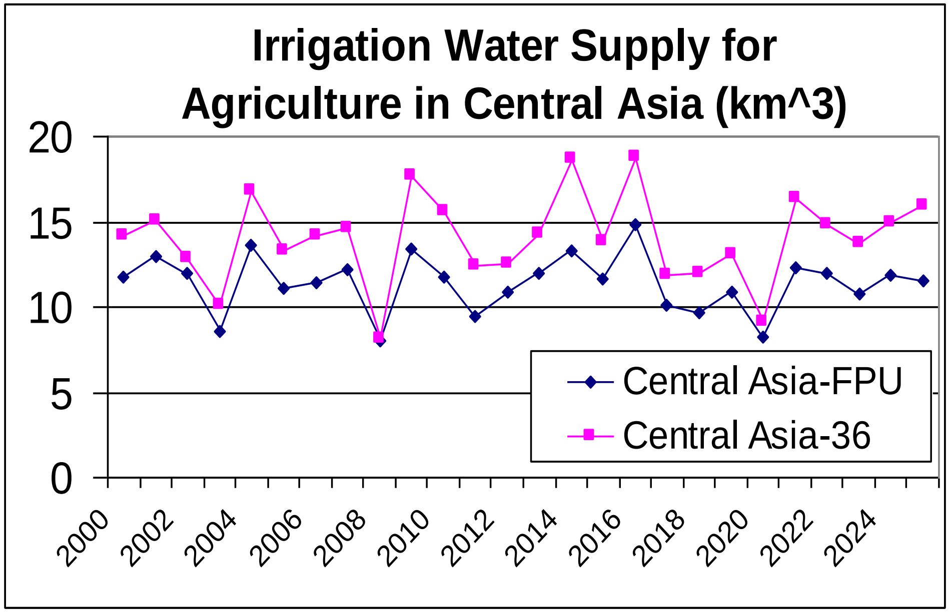
DRY

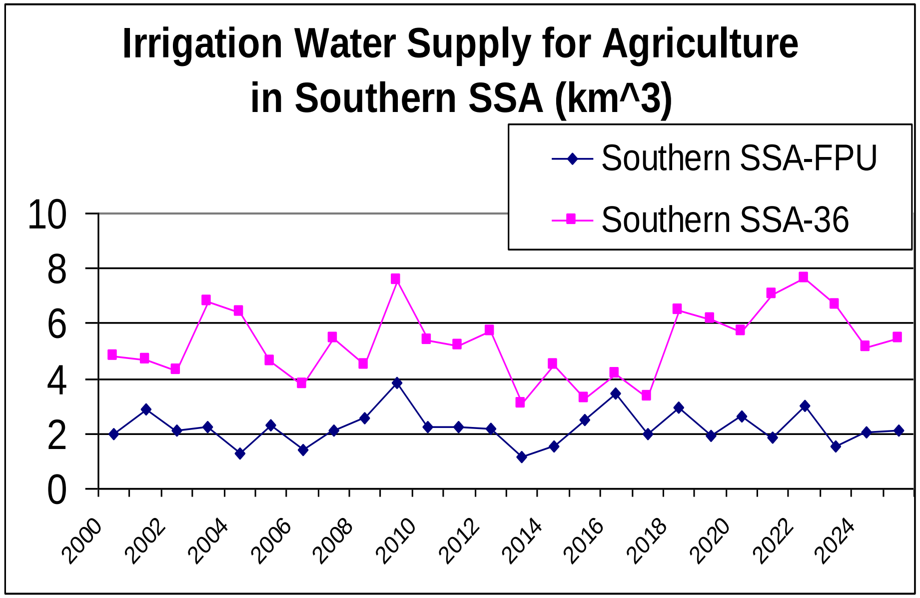


Irrigation Water Supply for Agriculture





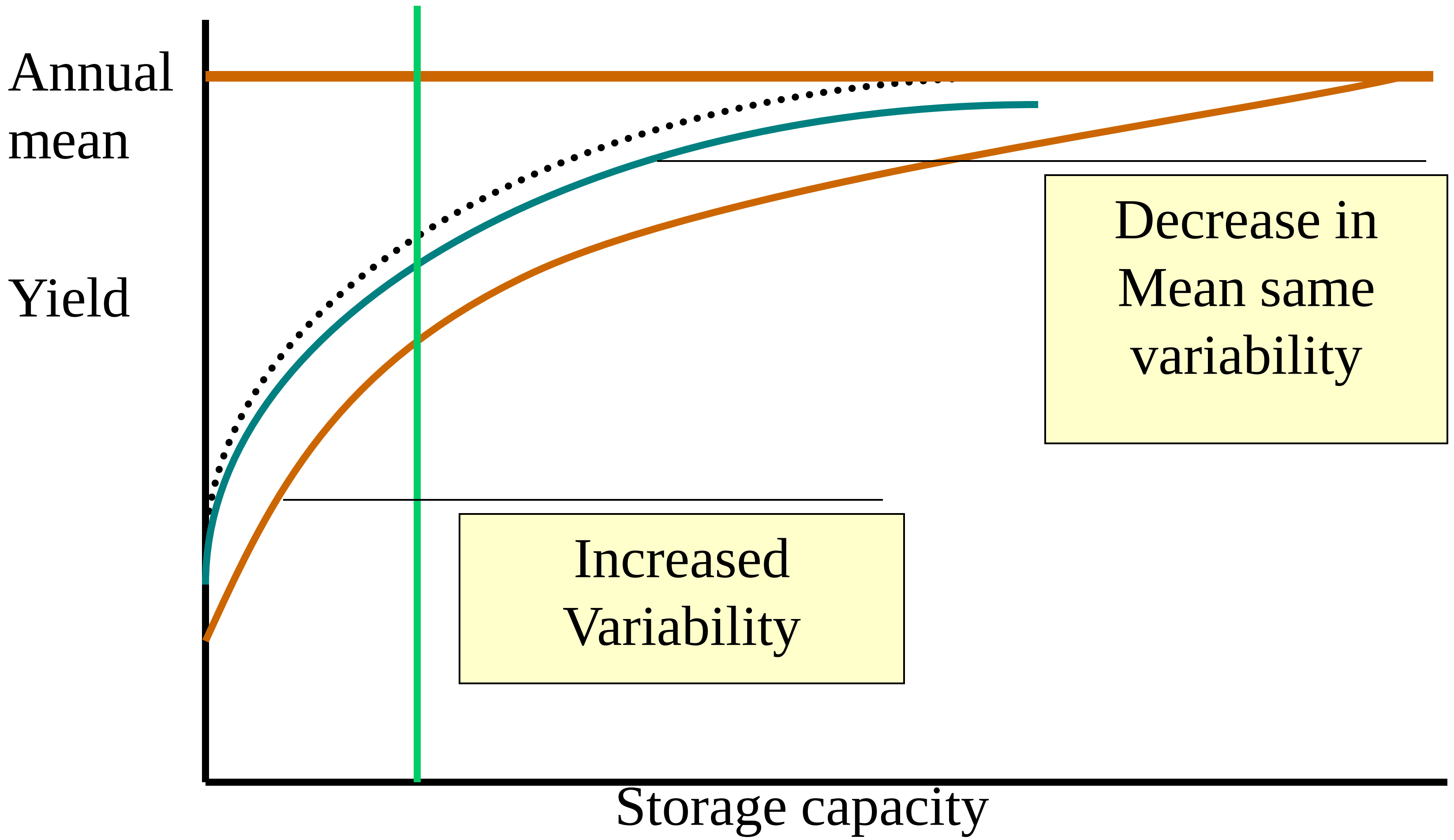




WATER MANAGEMENT

- Bring Water to Where it is needed when it is needed
- Great Environmental Costs
- Market Benefit
- Social Costs and Benefits

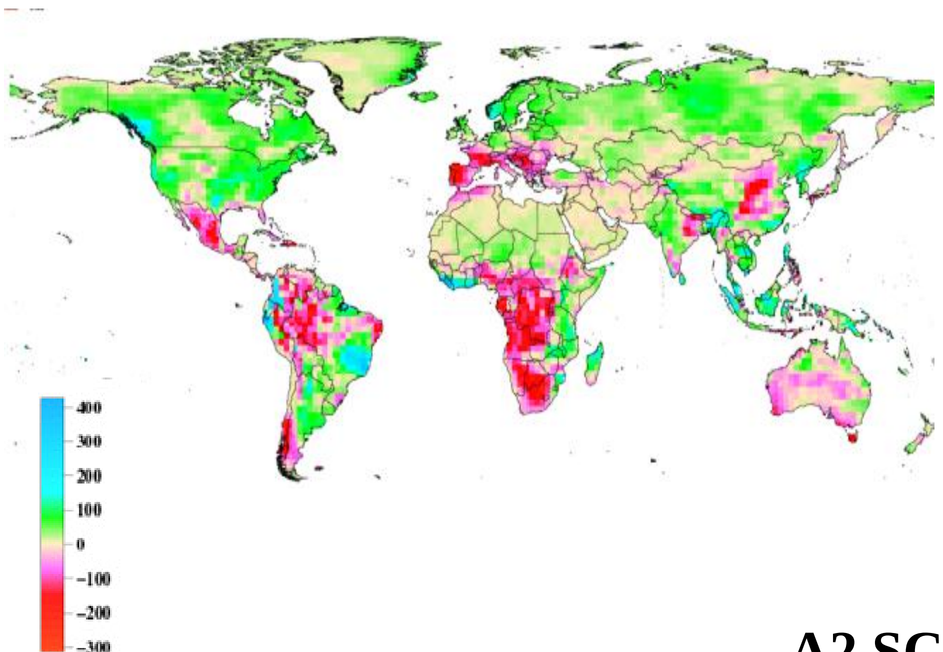
Storage Yield Curves

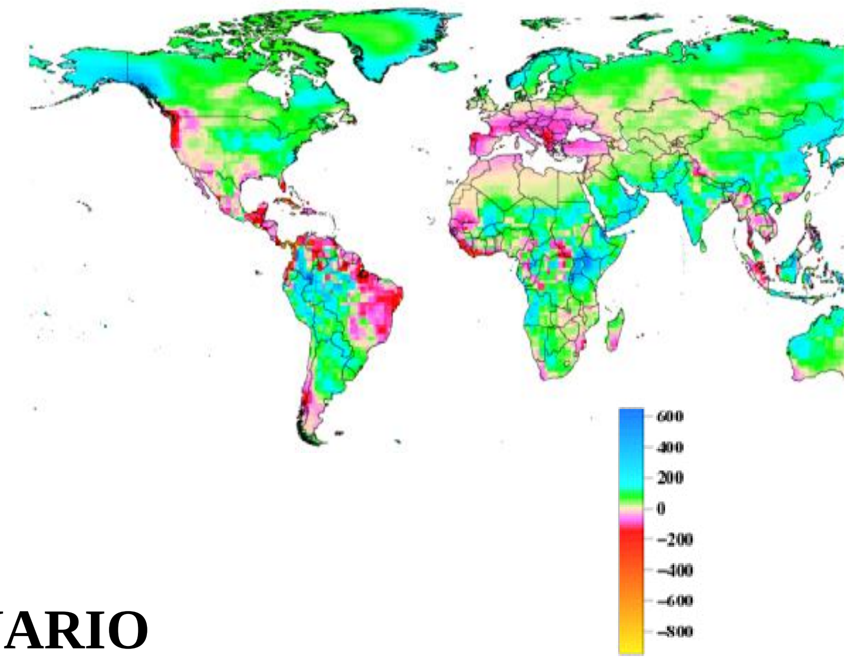


Global Wet and Dry

Change in average annual precipitation, 2000 – 2050

CSIRO (DRY) **NCAR (WET)**

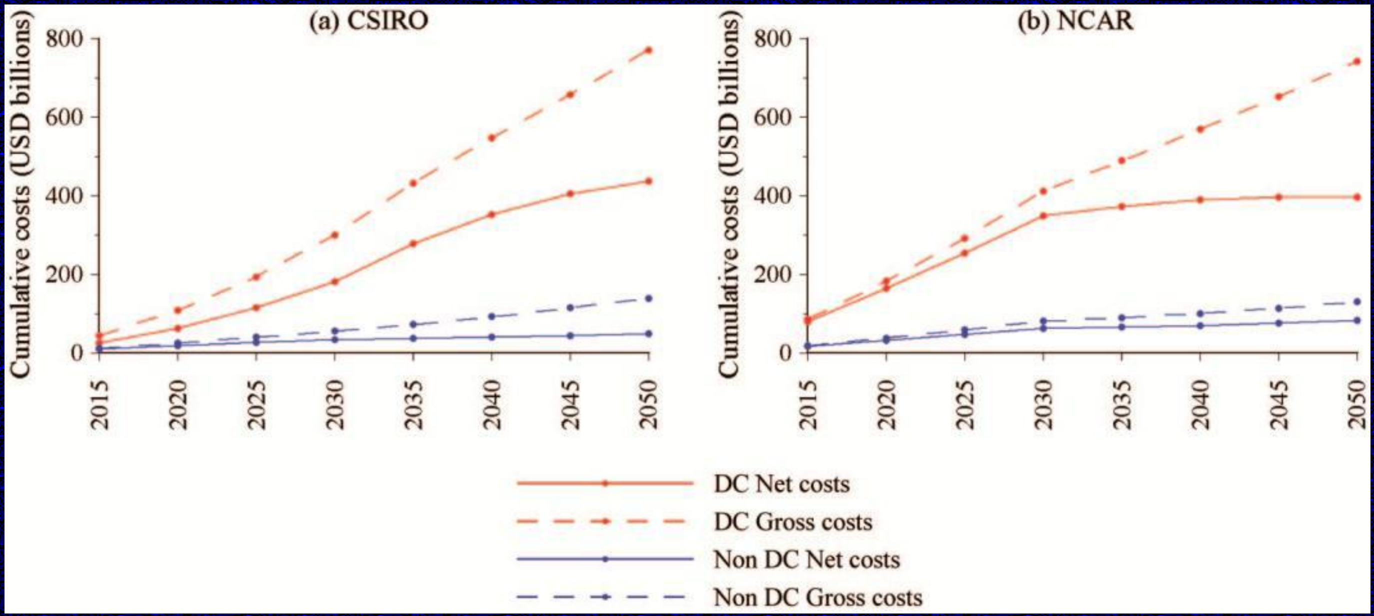




A2 SCENARIO

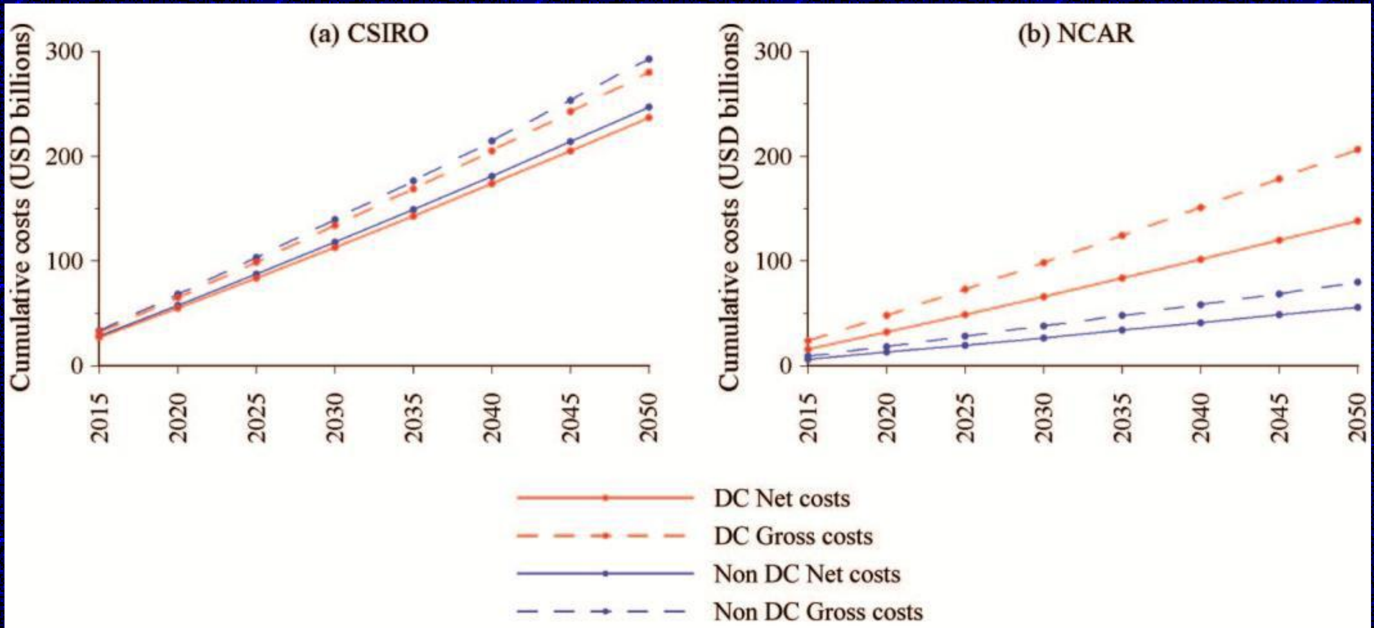
Two extreme GCMs used to estimate range of costs

Cost of Adaptation in 2050 (Ward et al 2010)

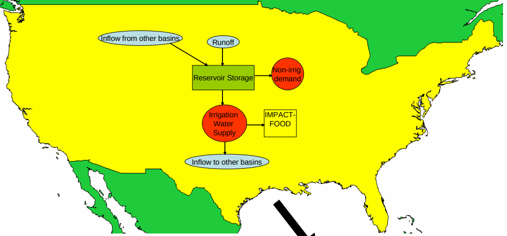


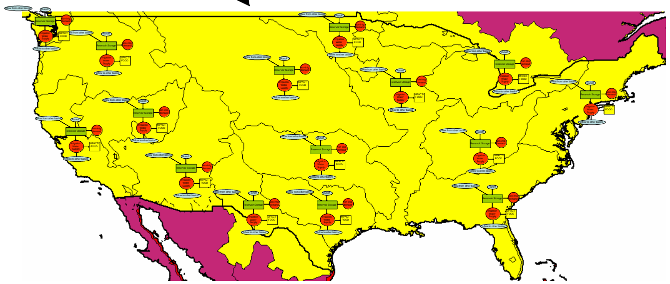
Water Supply

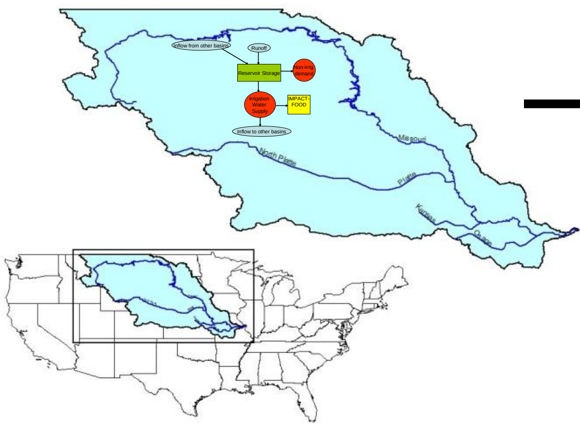
Flooding

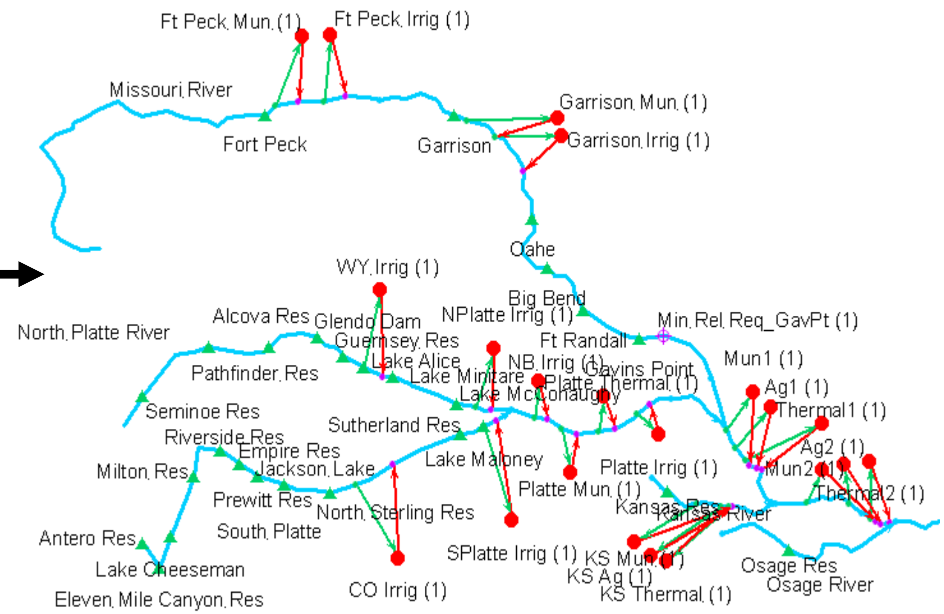


“What is the importance of spatial scale and management on river basin modeling for global food production?”

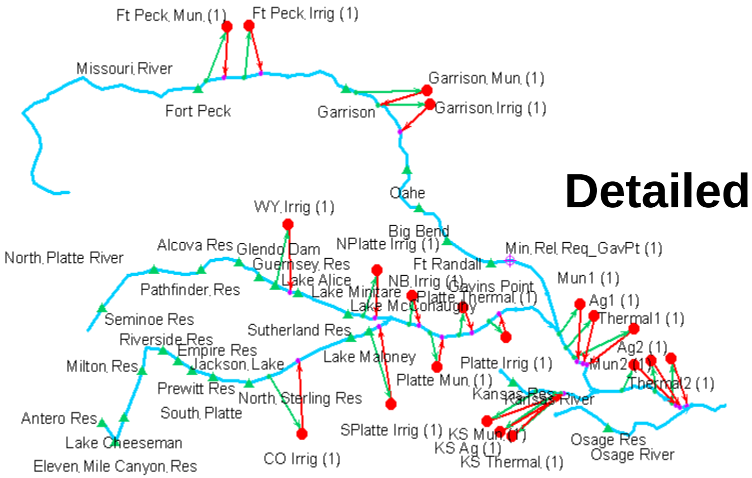


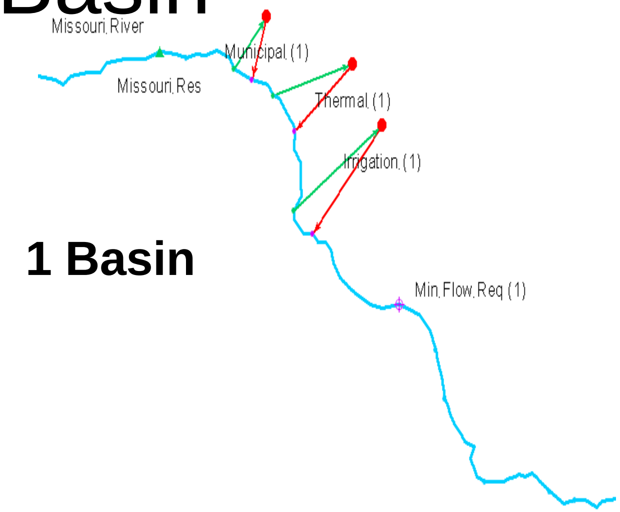


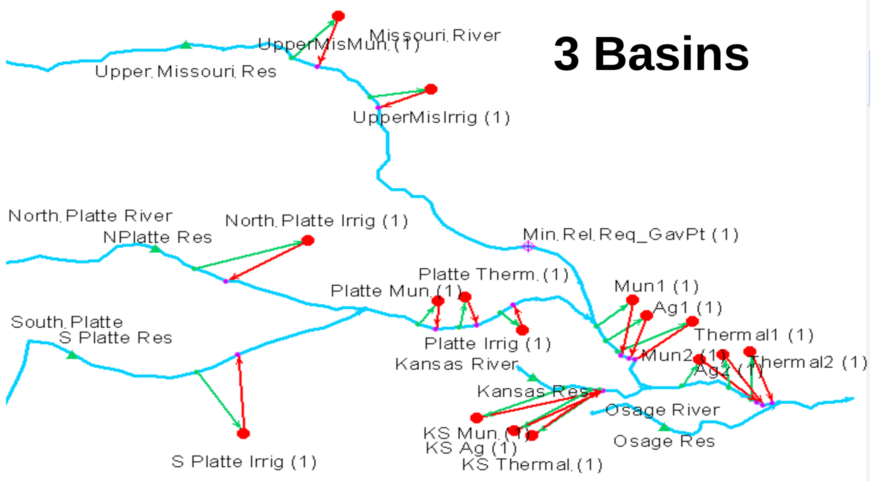


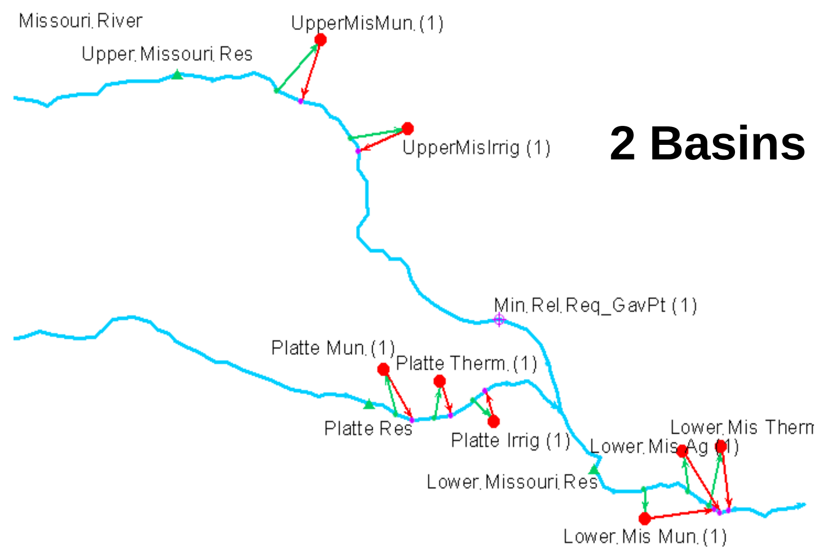


4 Spatial Scale Representations of Missouri River Basin

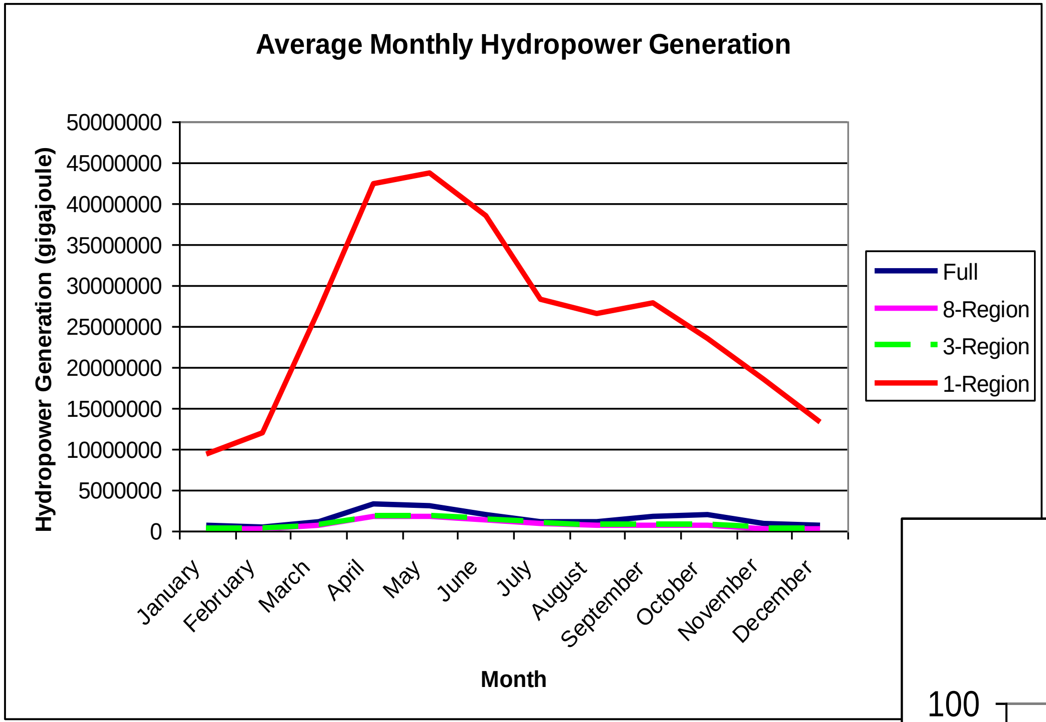


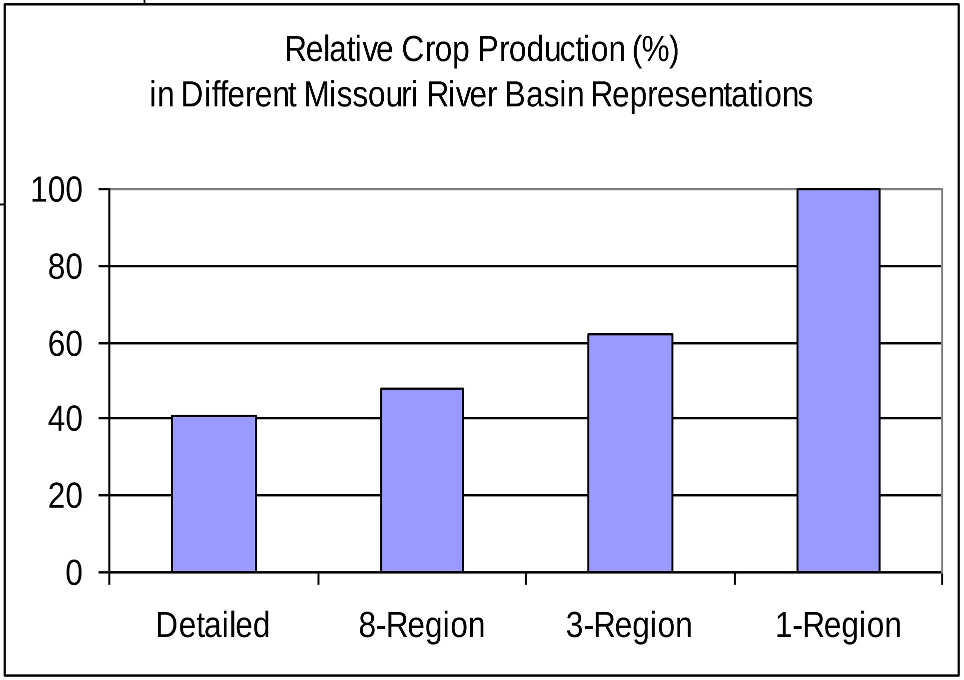




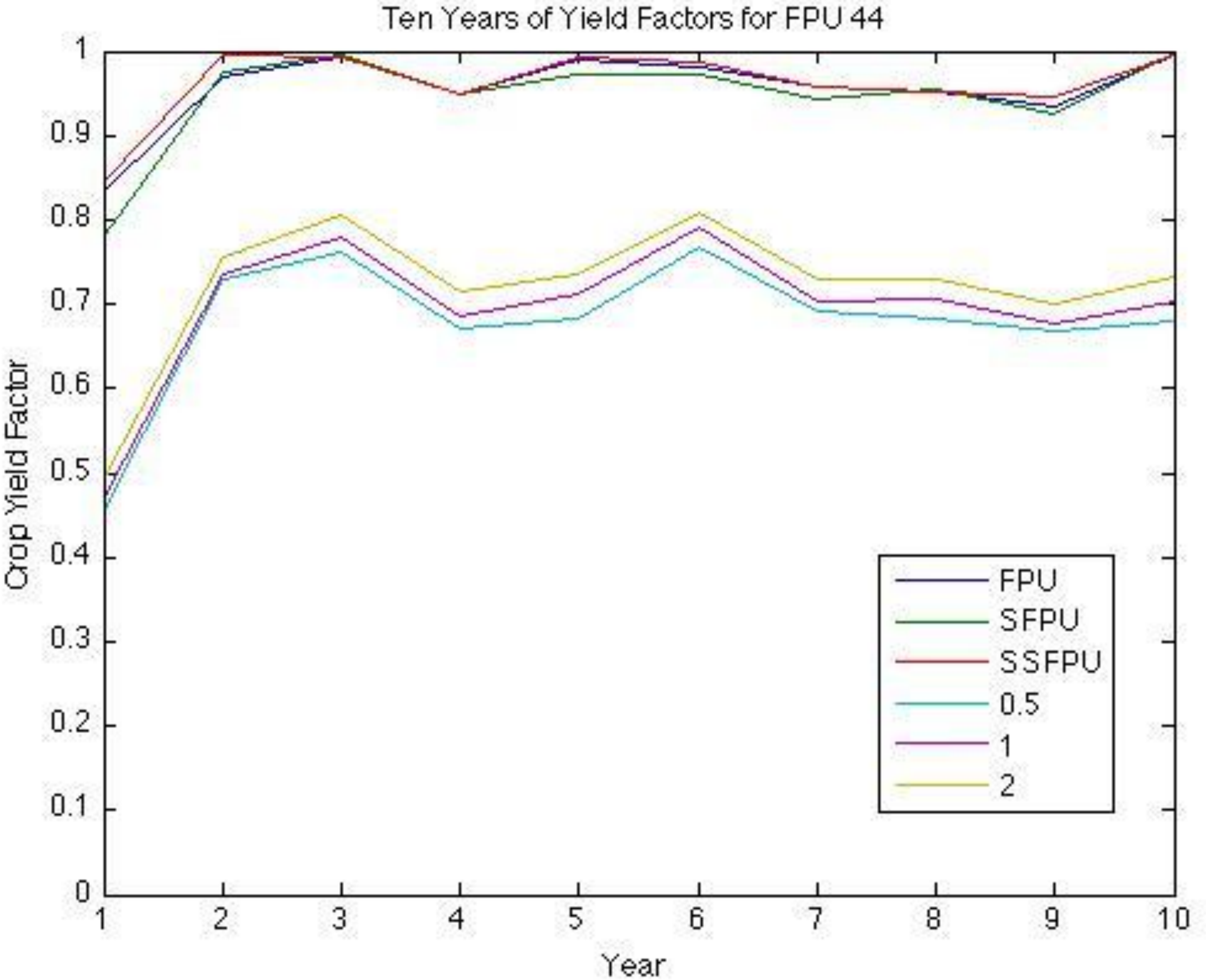


Average Monthly Hydropower Generation in each of the Missouri River Spatial Representations

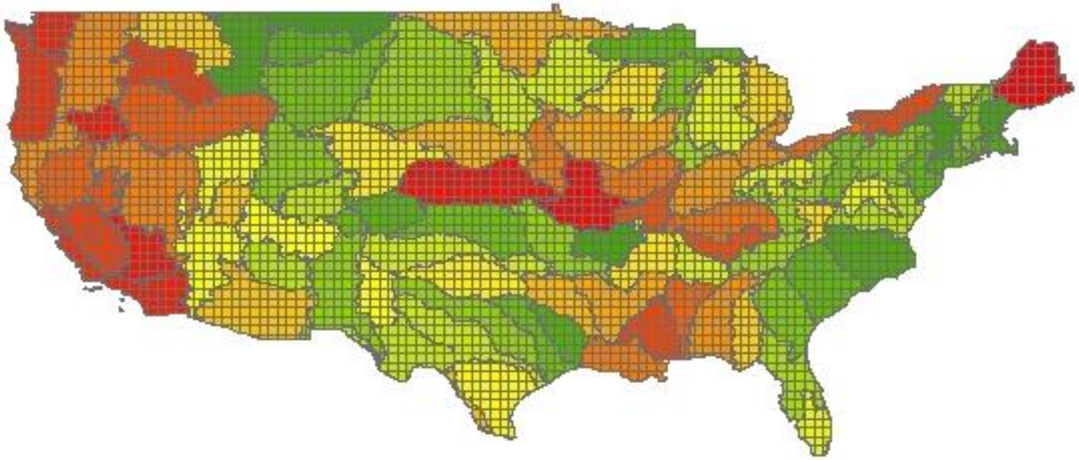




Spatial Resolution Impacts on Estimated Crop Water Stress (Farmer et al, 2010)

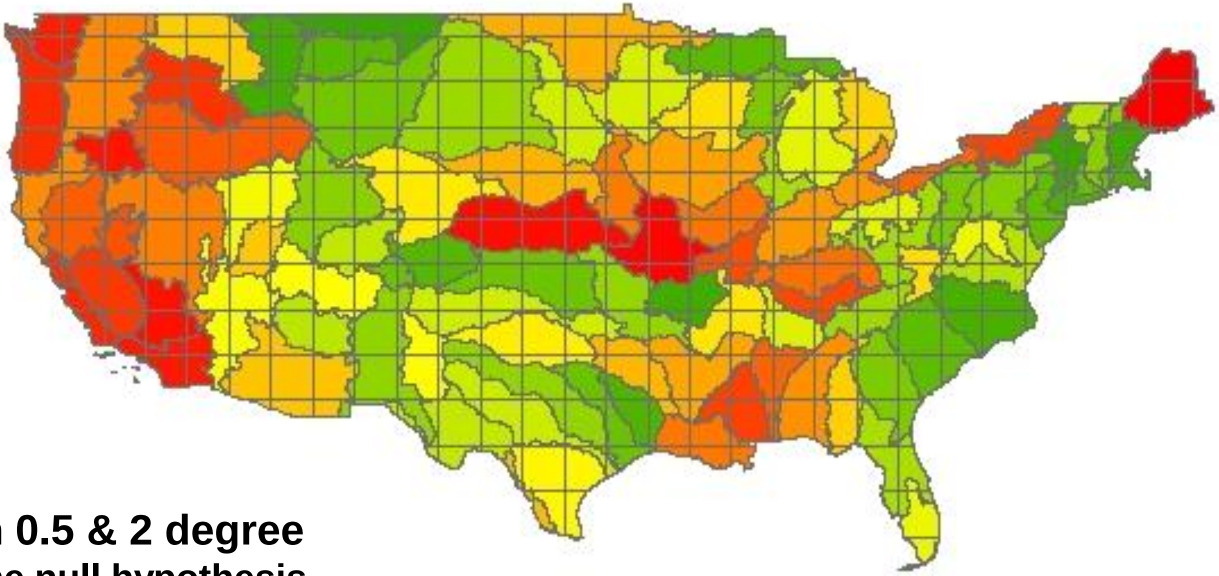


Spatial Unit of Crop Modeling (Farmer et al, 2010)



- 0.5 Degree 3000 cells
- 2 degree 180 cells

	0.5	1.0	2.0
0.5	1.0	0.80	0.08
1.0		1.0	0.13
2.0			1.0

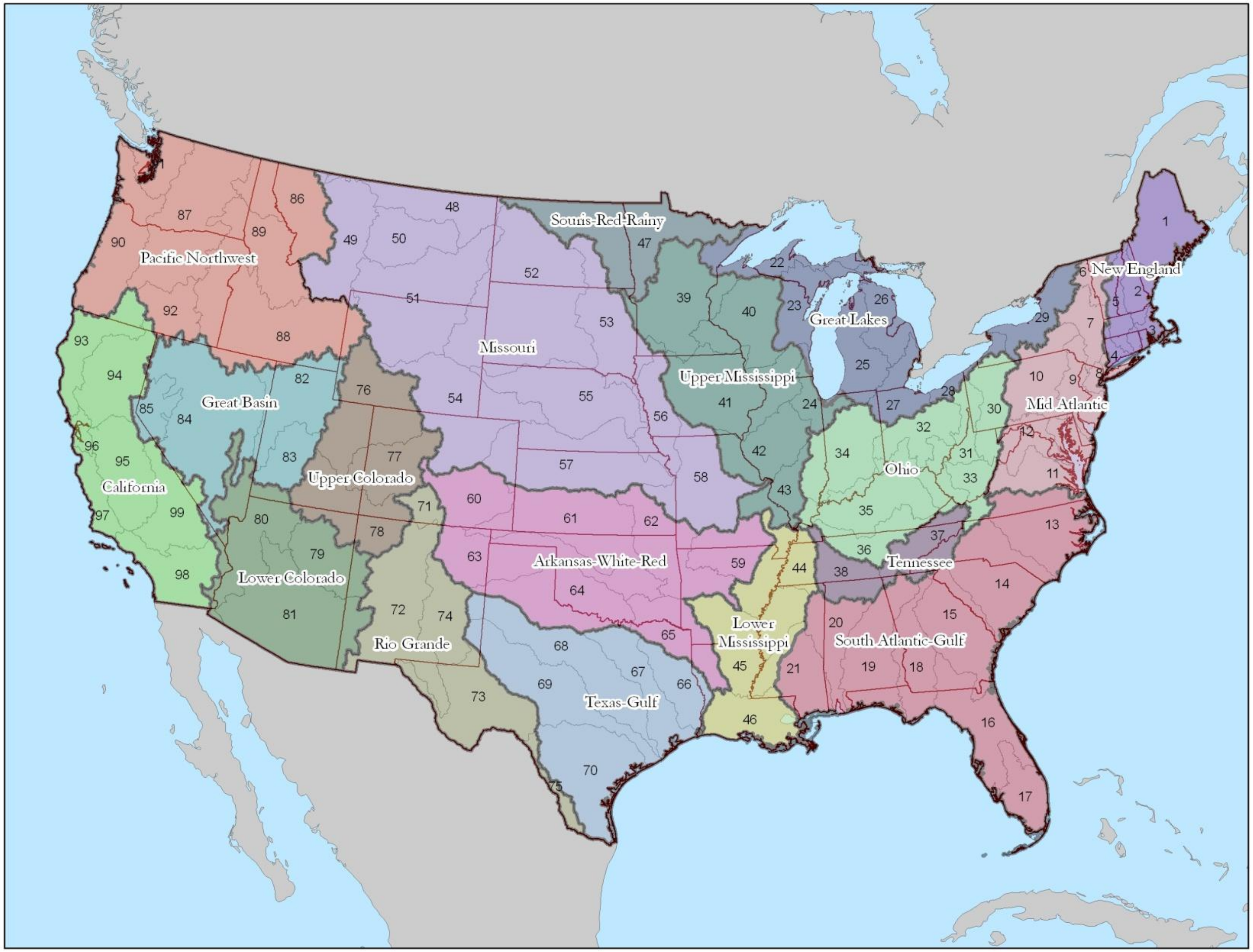


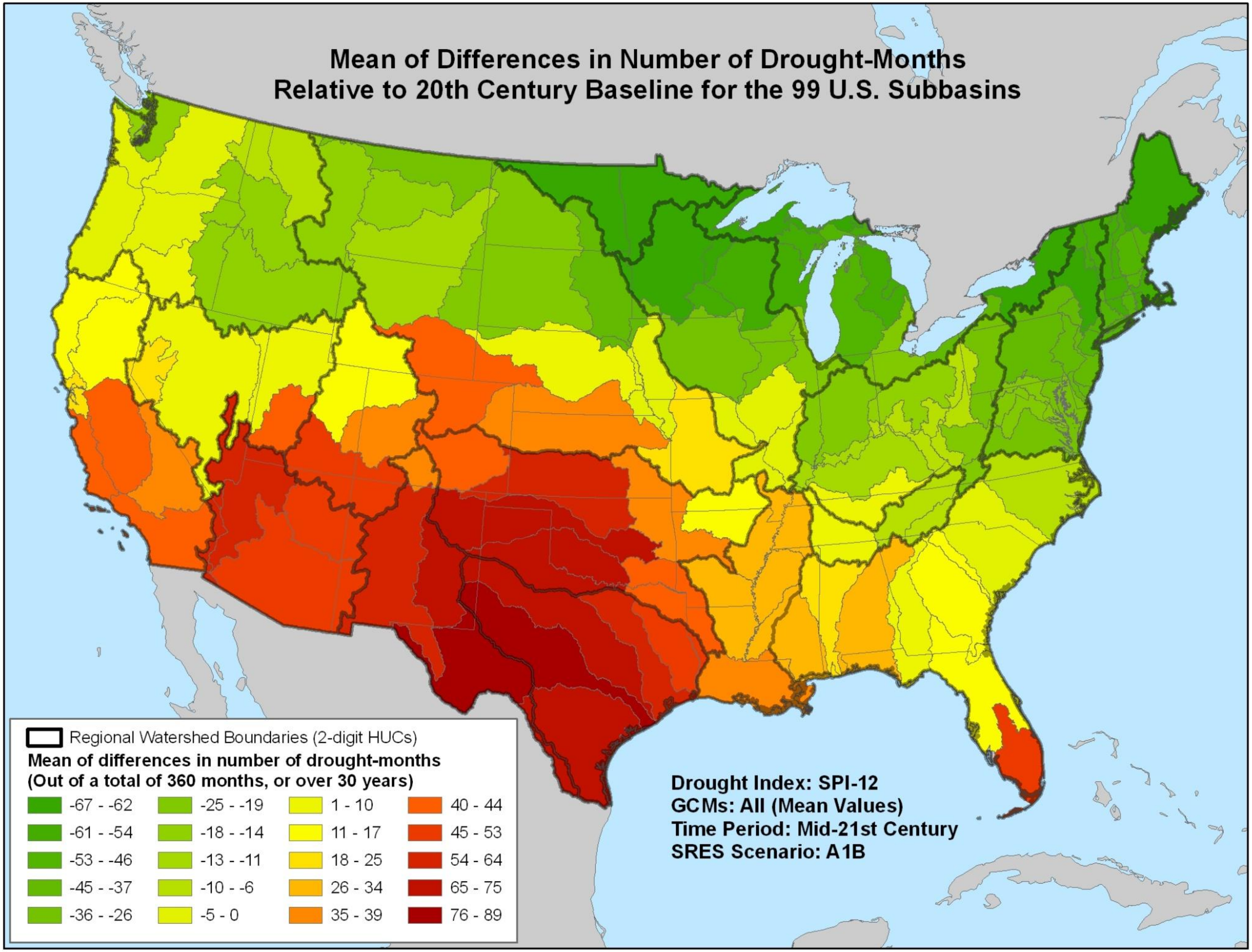
No Statistical Difference between 0.5 & 2 degree

A p-value less than 0.05 will reject the null hypothesis.

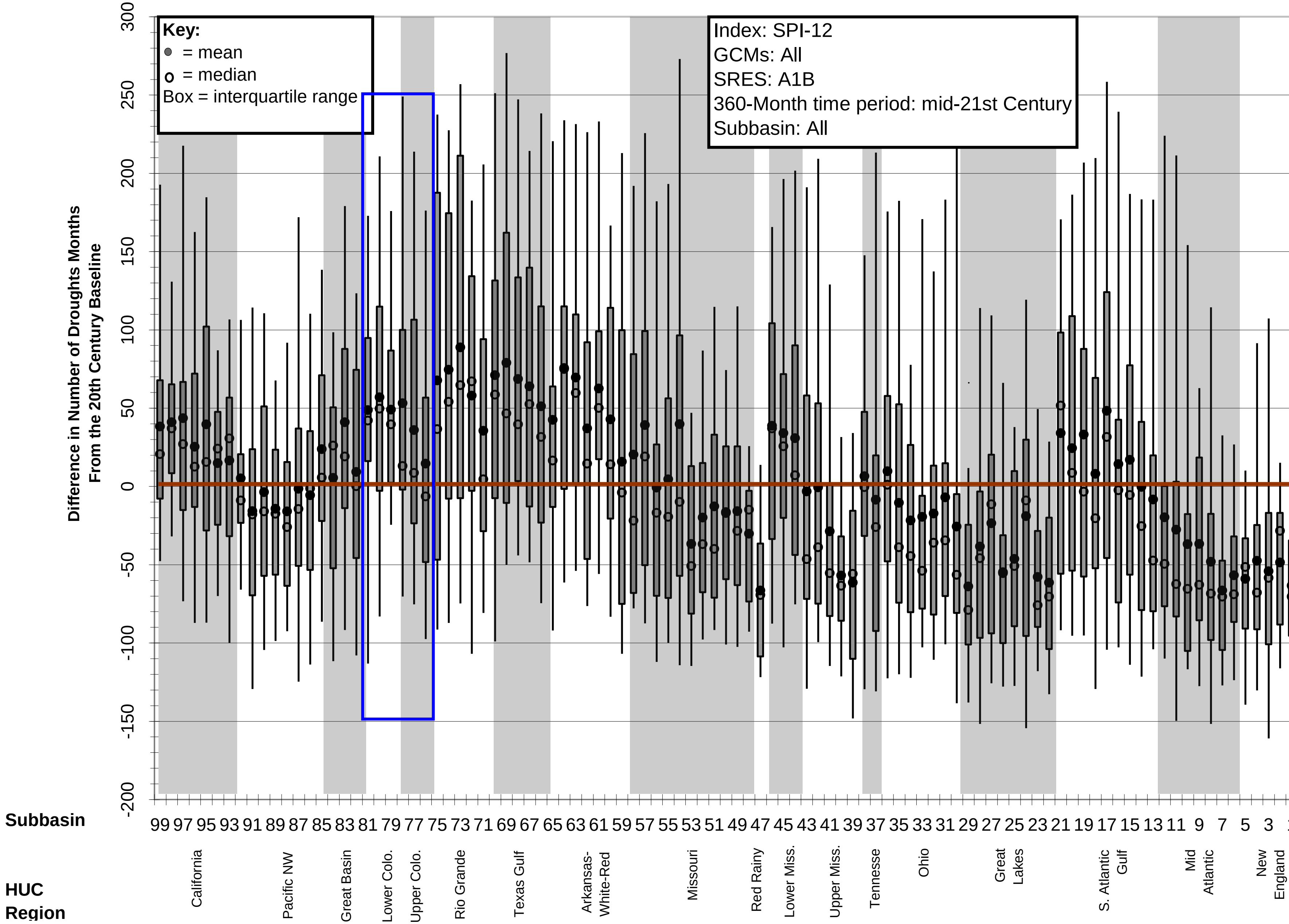
River Basin Spatial Scale for USA
30 to 99[1] basins

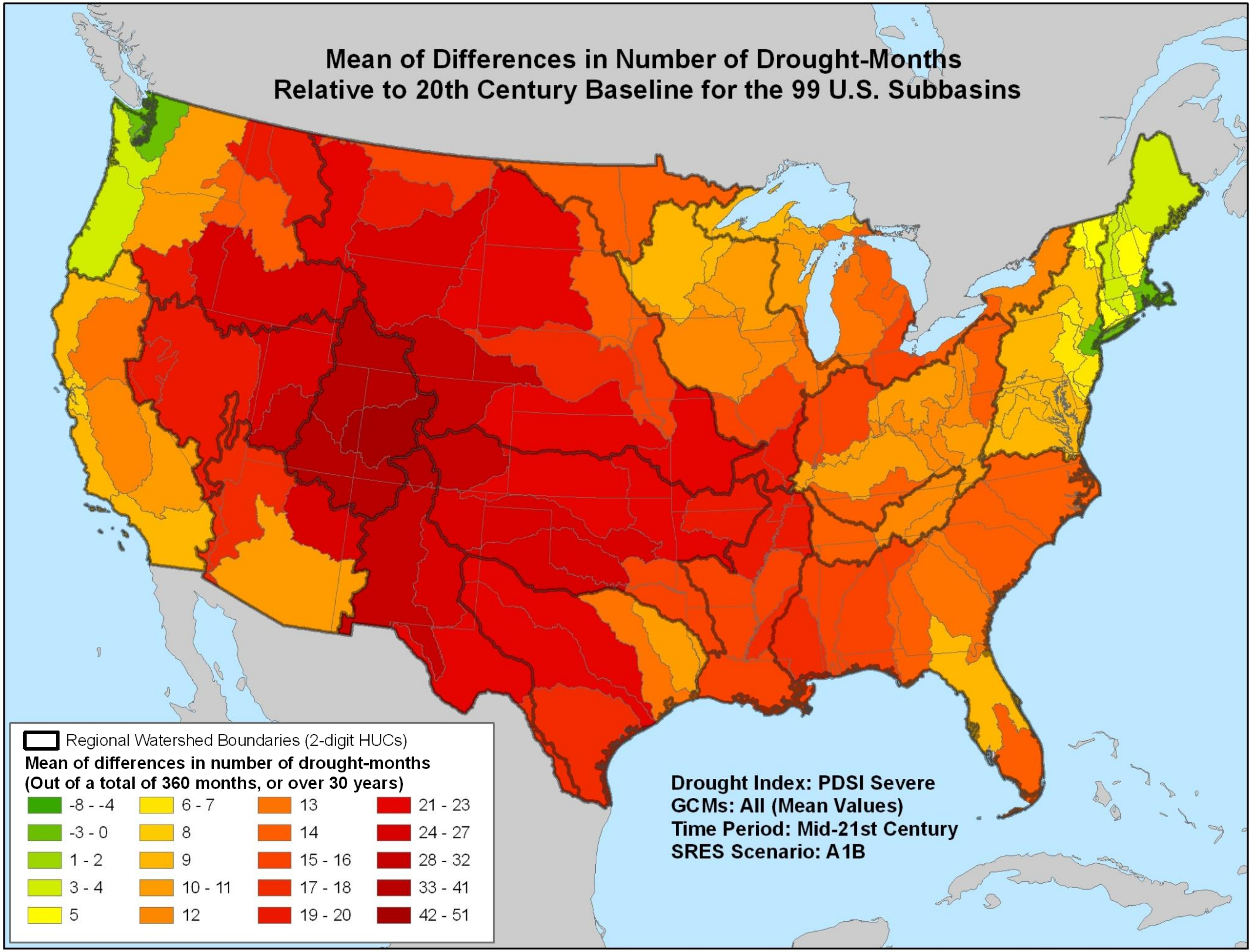
[1] Source: Subbasin Assessment Regions 1978 Water Resources Council, 2nd National Assessment

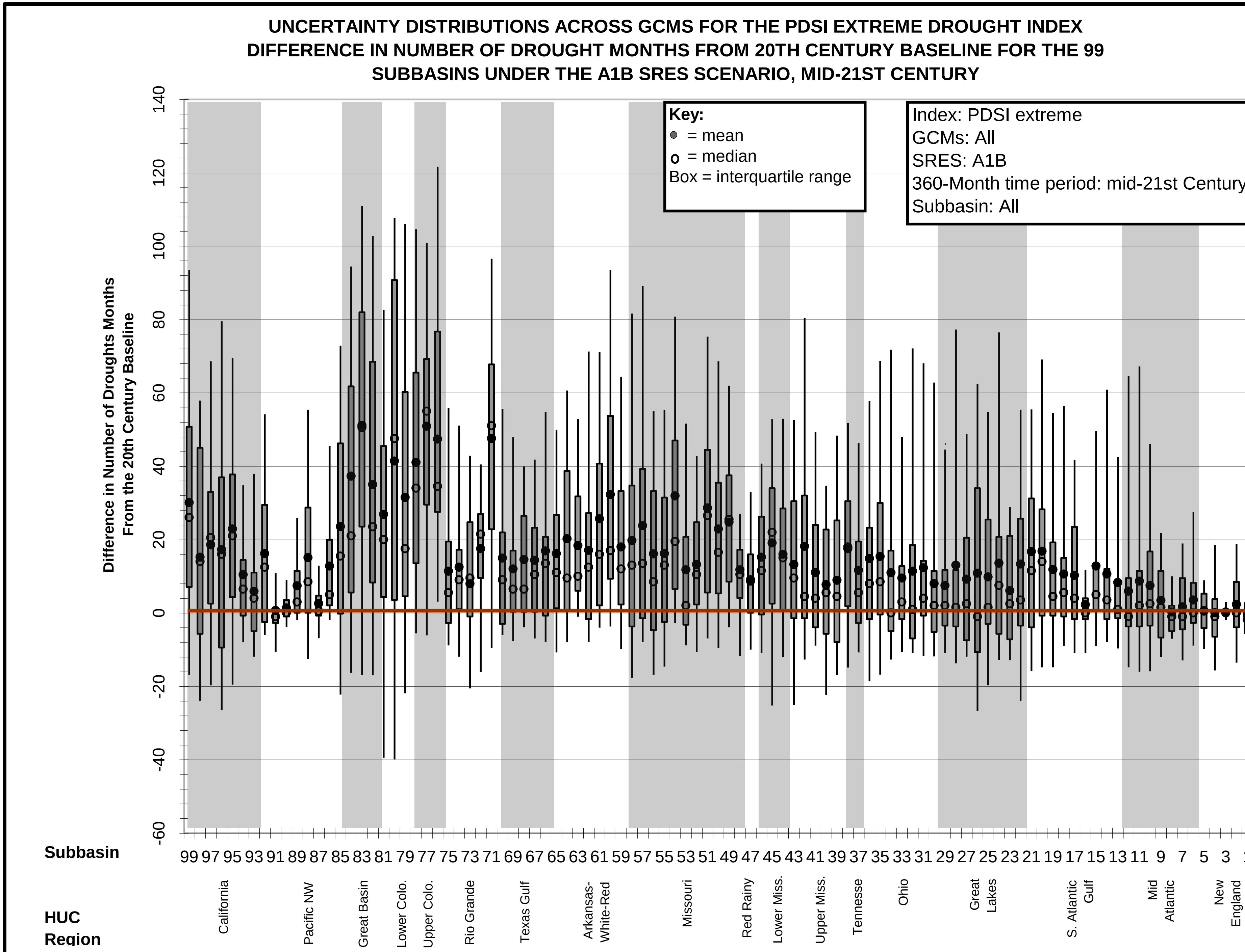



Mean of Differences in Number of Drought-Months
Relative to 20th Century Baseline for the 99 U.S. Subbasins
Regional Watershed Boundaries (2-digit HUCs)
Mean of differences in number of drought-months
(Out of a total of 360 months, or over 30 years)
-67 - -62
-61 - -54
-53 - -46
-45 - -37
-36 - -26
-25 - -19
-18 - -14
-13 - -11
-10 - -6
-5 - 0
1 - 10
11 - 17
18 - 25
26 - 34
35 - 39
40 - 44
45 - 53
54 - 64
65 - 75
76 - 89
Drought Index: SPI-12
GCMs: All (Mean Values)
Time Period: Mid-21st Century
SRES Scenario: A1B

UNCERTAINTY DISTRIBUTIONS ACROSS GCMS FOR THE SPI-12 DROUGHT INDEX DIFFERENCE IN NUMBER OF DROUGHT MONTHS FROM 20TH CENTURY BASELINE FOR THE 99 SUBBASINS UNDER THE A1B SRES SCENARIO, MID-21ST CENTURY




Mean of Differences in Number of Drought-Months
Relative to 20th Century Baseline for the 99 U.S. Subbasins
Regional Watershed Boundaries (2-digit HUCs)
Mean of differences in number of drought-months
(Out of a total of 360 months, or over 30 years)
-8 - -4
-3 - 0
1 - 2
3 - 4
5
6 - 7
8
9
10 - 11
12
13
14
15 - 16
17 - 18
19 - 20
21 - 23
24 - 27
28 - 32
33 - 41
42 - 51
Drought Index: PDSI Severe
GCMs: All (Mean Values)
Time Period: Mid-21st Century
SRES Scenario: A1B



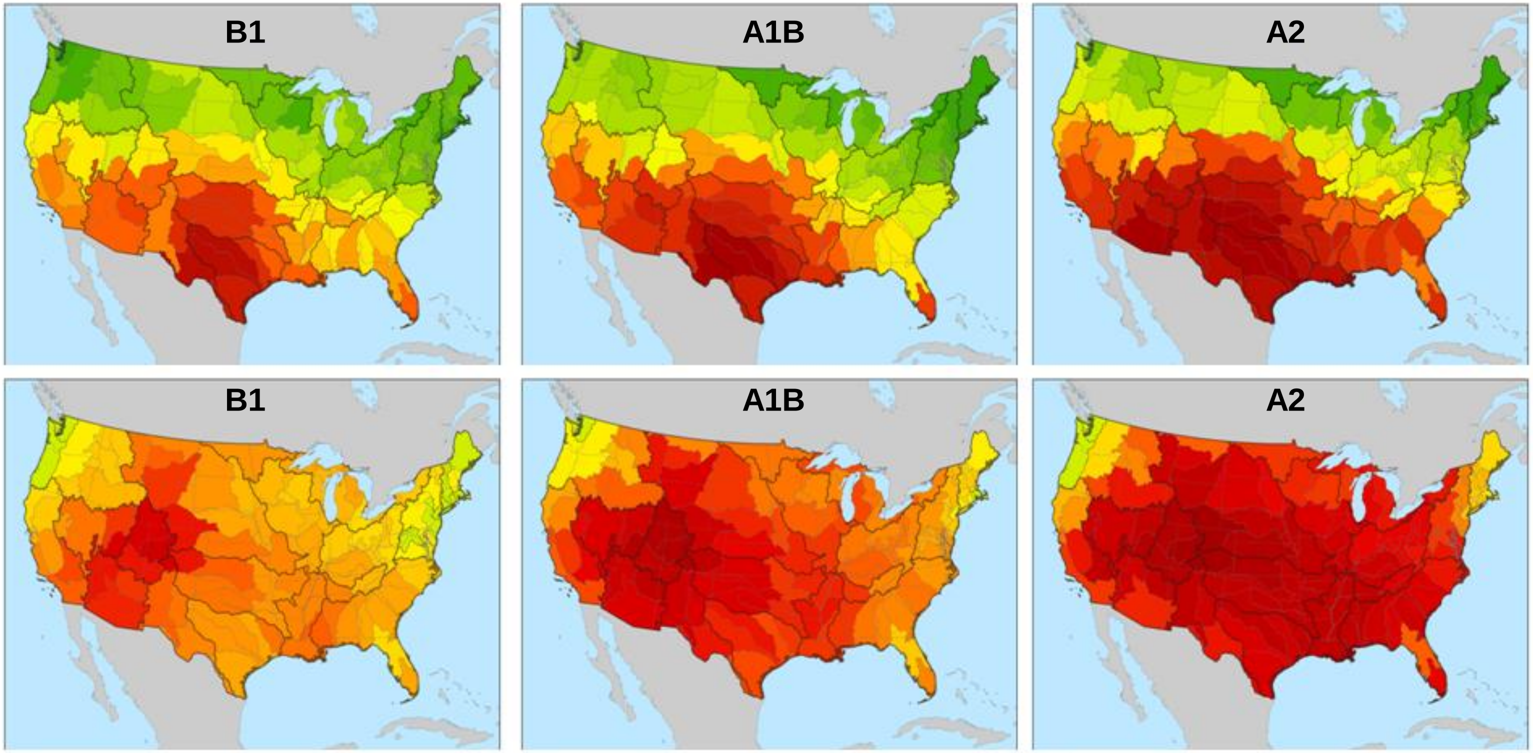
UNCERTAINTY DISTRIBUTIONS ACROSS GCMS FOR THE PDSI EXTREME DROUGHT INDEX
DIFFERENCE IN NUMBER OF DROUGHT MONTHS FROM 20TH CENTURY BASELINE FOR THE 99
SUBBASINS UNDER THE A1B SRES SCENARIO, MID-21ST CENTURY
Key:
= mean
= median
Box = interquartile range
Index: PDSI extreme
GCMs: All
SRES: A1B
360-Month time period: mid-21st Century
Subbasin: All
Difference in Number of Droughts Months
From the 20th Century Baseline
Subbasin
HUC
Region
California
Pacific NW
Great Basin
Lower Colo.
Upper Colo.
Rio Grande
Texas Gulf
Arkansas-White-Red
Missouri
Red Rainy
Lower Miss.
Upper Miss.
Tennesse
Ohio
Great Lakes
S. Atlantic Gulf
Mid Atlantic
New England

Mean Changes in Drought Index Values from Baseline

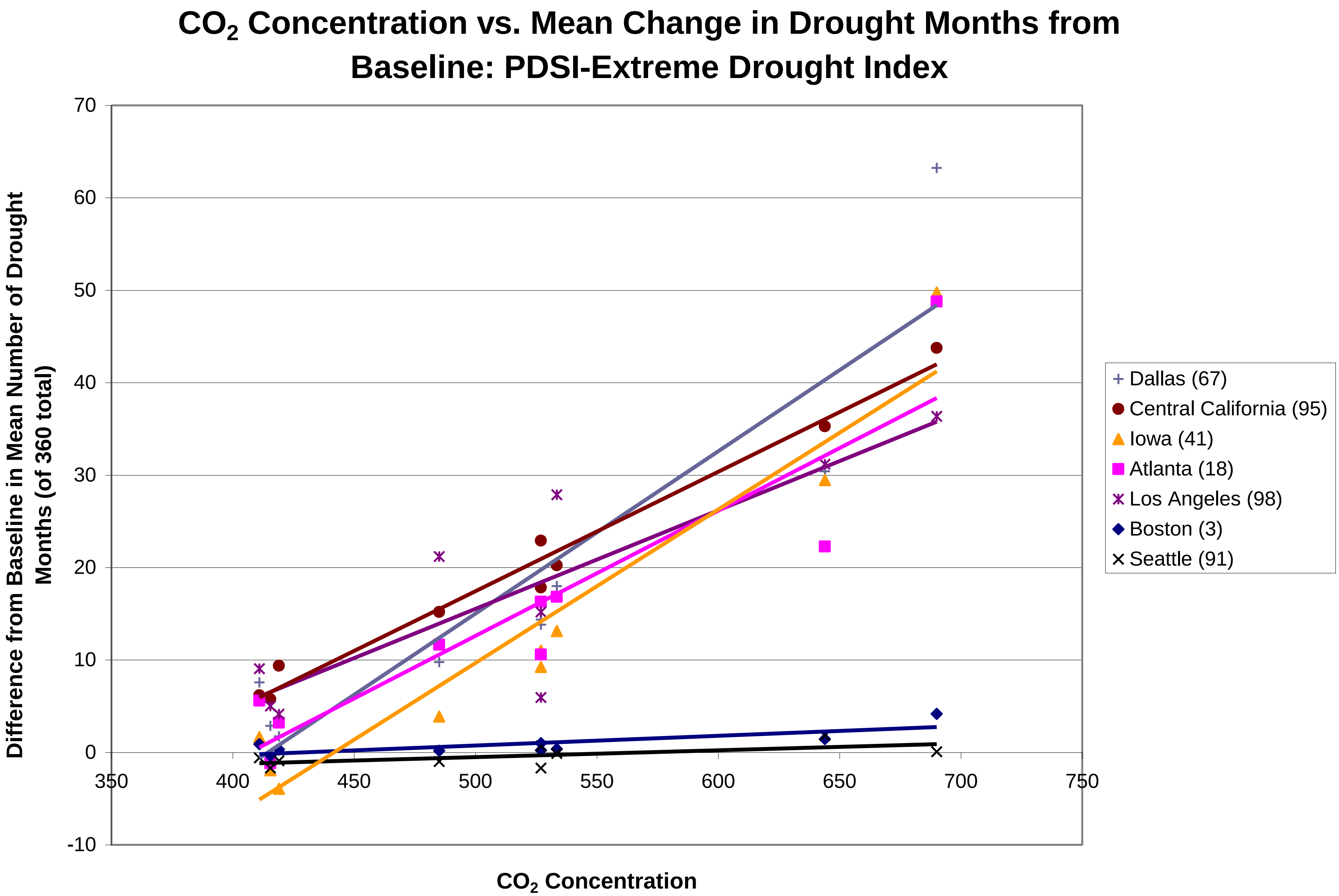
B1, A1B, and A2 SRES Scenarios in Late 21st Century (Strzepek et al 2010)

SPI-12

PDSI Extreme

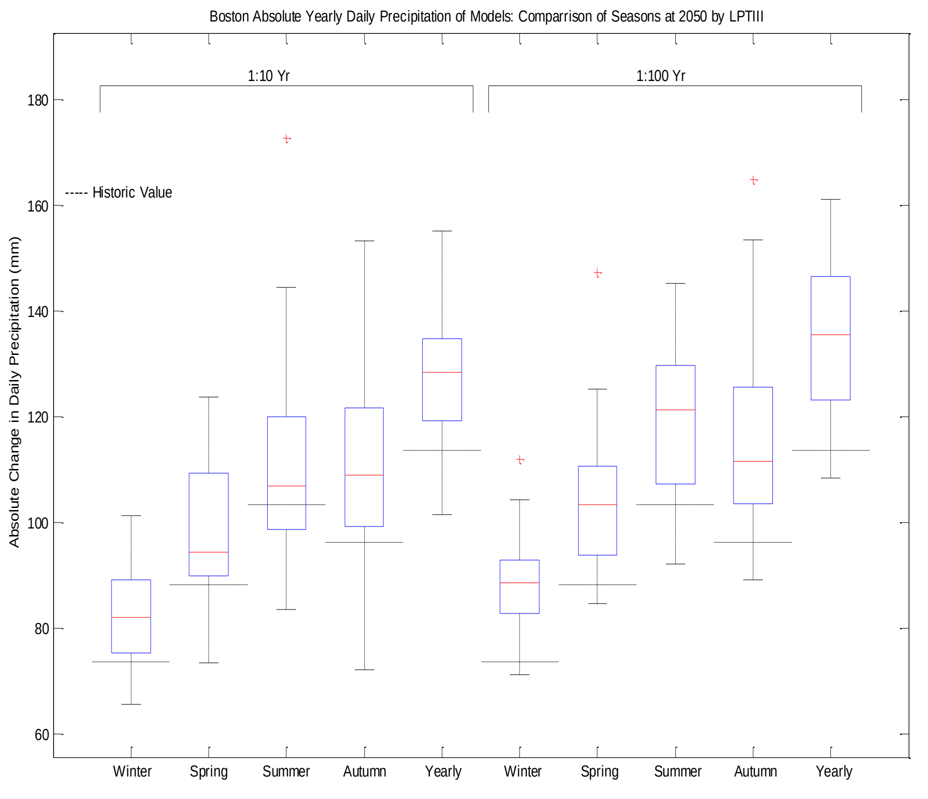


Observation 4b: Emissions have a more pronounced effect on droughts when both temperature and precipitation are considered.



Boston Design Storm 2050

Current Uncertainty in 100 yr Storm much greater than range of GCM Changes



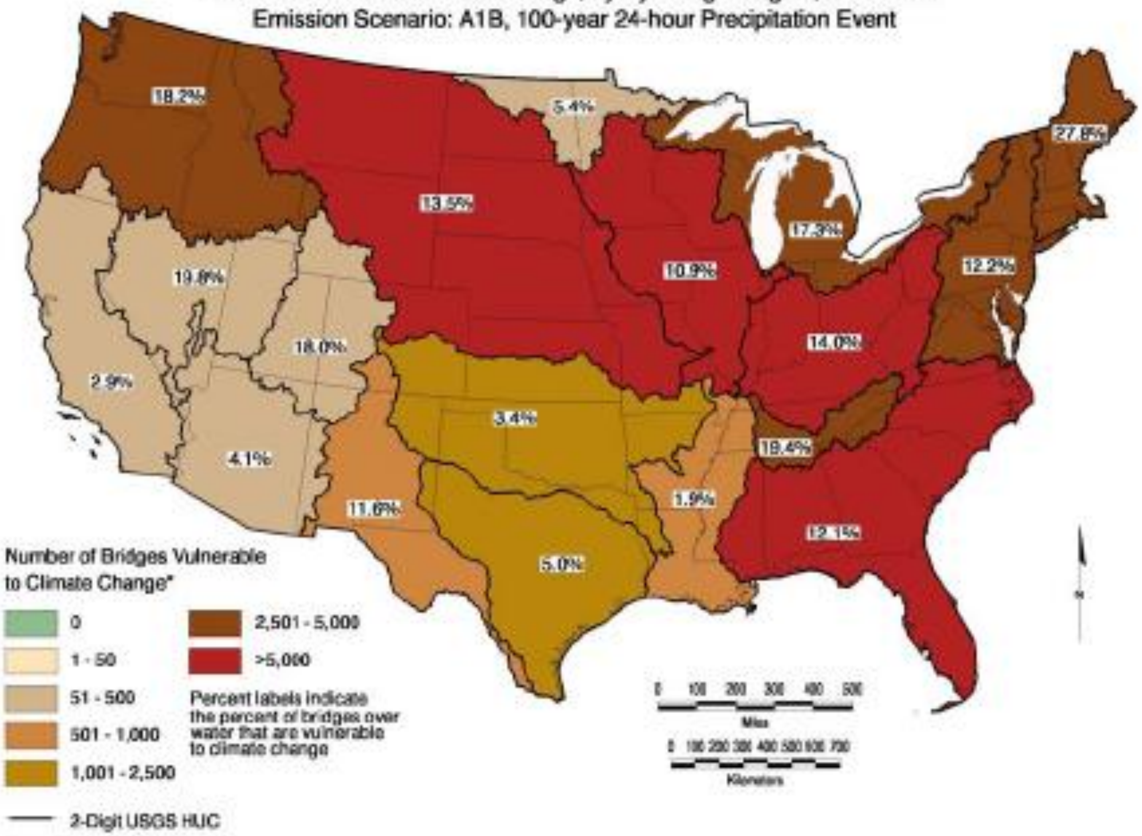
CC Impacts on Roadway Bridges USEPA by Stratus

Table 13. Number of currently deficient bridges per 2-digit HUC vulnerable to climate change for the historical 100-year, 24-hour storm. This includes currently deficient bridges with a projected increase in modeled flow of more than 20% for three future emissions scenarios (A2, A1B, B1) and two time periods (2055, 2090).

HUC	A2 2055	A1B 2055	B1 2055	A2 2090	A1B 2090	B1 2090
1	2,430	3,026	1,428	2,904	2,717	2,726
2	7,395	3,871	3,409	8,734	8,100	4,749
3	15,106	7,772	6,860	23,072	19,552	3,987
4	4,556	3,675	4,482	4,975	5,198	4,629
5	11,996	8,458	6,350	12,654	12,870	10,156
6	2,875	3,105	3,677	4,306	4,306	2,980
7	7,246	6,030	5,591	8,129	8,405	4,354
8	6,114	541	1,404	11,761	4,669	1,325
9	351	221	343	351	356	325
10	11,722	8,205	6,539	10,329	12,453	9,979
11	5,774	1,648	925	6,516	5,481	4,612
12	6,254	1,783	1,440	7,433	5,300	9,617
13	453	426	291	528	515	538
14	502	274	250	400	405	486
15	773	285	123	752	493	301
16	545	360	463	515	545	534
17	4,665	2,675	1,666	5,545	3,688	3,011
18	2,357	459	2,087	2,530	2,551	496
Total	91,114	52,814	47,328	111,434	97,604	64,805

Impacts on Roadway Bridges

Projected Number and Percent of Highway Bridges At Risk from Increased Peak Flows Due to Climate Change, by Hydrologic Region, 2046-2065
Emission Scenario: A1B, 100-year 24-hour Precipitation Event

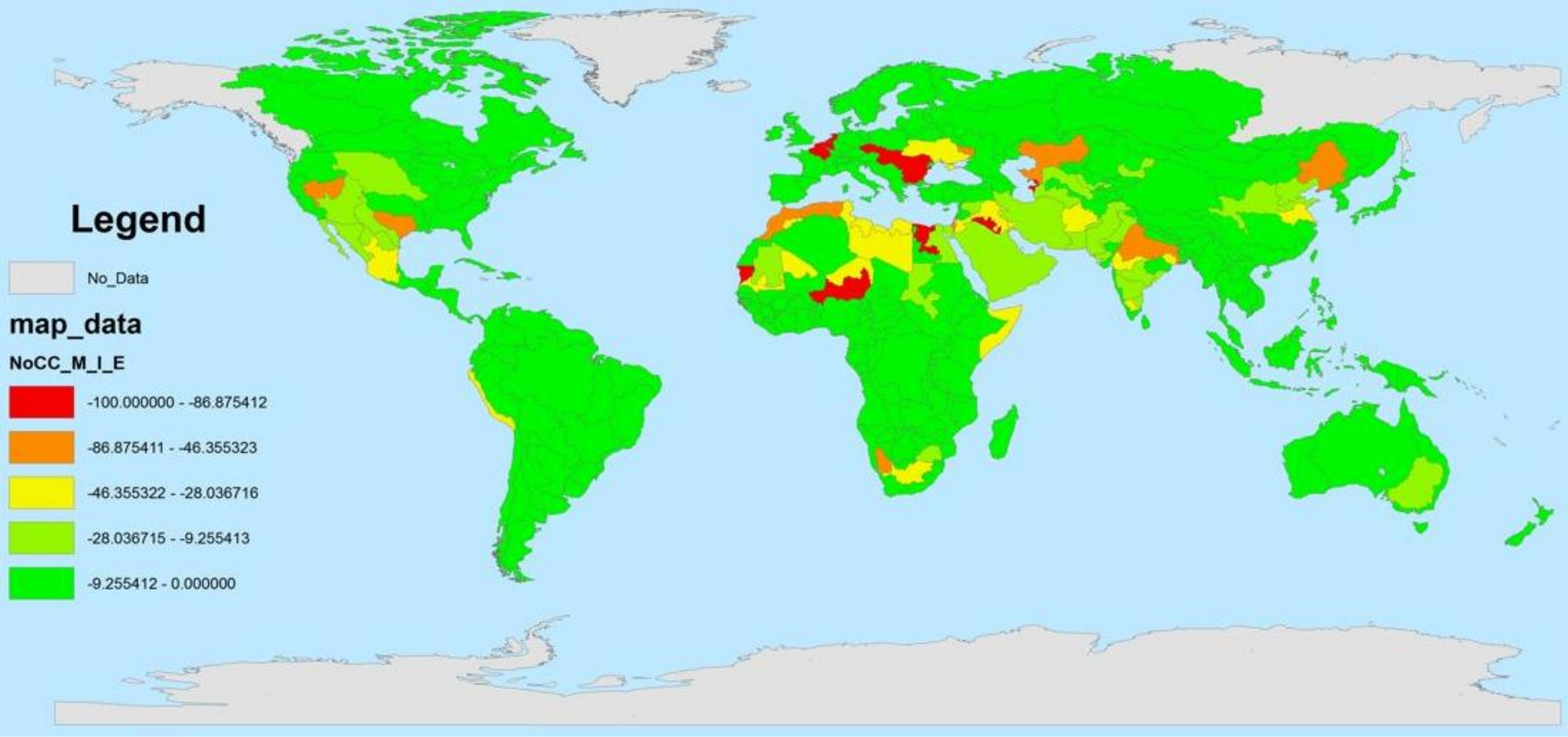


Based on Average of GCMs: CCCMA CGCM 3.1, CNRM CM3.0, and GFDL 2.0

*Includes currently deficient bridges identified from National Bridge Inventory and located within hydrologic regions with a projected increase in modeled flow of greater than 20 percent, plus currently acceptable bridges located on non-sandy soil with a projected increase in modeled flow of greater than 60 percent, plus currently acceptable bridges located on sandy soil with a projected increase in modeled flow of greater than 100 percent from time period 1981-2000 to 2046-2065.

Figure 10. 2046–2065, 100-year, 24-hour storm, Scenario A1B.

Threats to Existing Ag Water (Strzepek & Boehlert, 2010)



Threats to Existing Ag Water

Foresight Region	2000 Agricultural Withdrawals (billion m^3)	No Climate Change		
		2050 M&I	EFRs	2050 M&I and EFRs
World	**2,946**	**7.3%**	**9.4%**	**17.7%**
Europe	**263**	**2.5%**	**7.7%**	**14.4%**
European Union	95	0.7%	12.8%	18.7%
Northwestern Europe	16	4.5%	11.7%	8.2%
United Kingdom	0.6	0.0%	0.0%	0.0%
Former Soviet Union	186	3.2%	10.0%	19.7%
Africa	**246**	**9.8%**	**5.8%**	**15.8%**
Sub-Saharan Africa	50	11.9%	7.2%	16.4%
Nile River Basin	146	9.1%	0.2%	9.2%
North America	**255**	**-0.1%**	**15.2%**	**14.9%**
Asia	**2,060**	**8.8%**	**8.9%**	**18.6%**
China	558	2.7%	7.3%	10.1%
India	866	13.5%	12.1%	27.7%
Latin America and the Caribbean	**182**	**3.8%**	**12.3%**	**16.1%**
Brazil	21	0.0%	0.0%	0.0%
Oceania	**50**	**0.2%**	**14.3%**	**14.5%**

Climate Change Threats to Ag Water

	Historic	WET	DRY
World	17.7	16.5	16.9
Europe	14.4	12.9	20.4
Africa	15.8	16.9	17.1
N.America	14.9	13.6	12
Asia	18.6	16.7	16.8
Latin Amer	16.1	19.9	16.8
Oceania	14.5	14.5	14.5

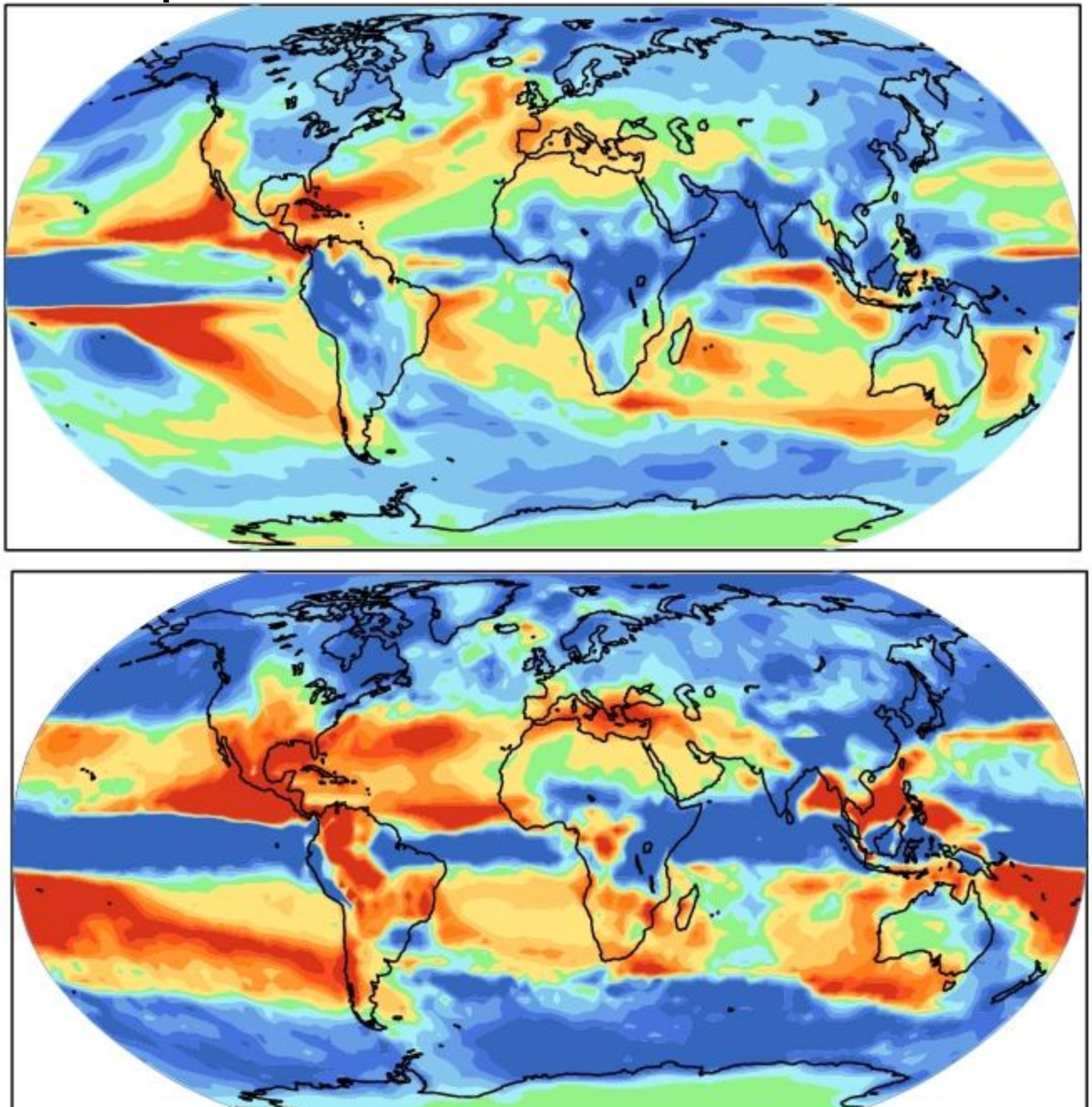
Water For Environment versus AG - Happening

- **Australian farmers are furious about a government concession to nature Australia's water war**
- AFTER a ten-year drought, farmers along the Murrumbidgee River now face ruin from a devastating flood. But it is the government that riles them as much as any caprice of nature. Last month officials called for a cut of nearly 40% in the volume of river water they take for irrigation. At a rowdy meeting in Narrandera, a river town, John Bonetti, a third-generation farmer, drew cheers from about 900 farmers when he told visiting bureaucrats and scientists, “If you think this is the end of the fight, I can assure you it’s only the bloody start.”

Summary

- SCALE MATTERS
- Cannot sum water impacts across sectors for Impacts and especially Adaptation must model Basin Scale Water Mgt Systems (Smith, Hurd next talk)
- FLOODING VERY IMPORTANT
  - Need “additional” information from GCMs
- CLIMATE CHANGE IN THE CONTEXT OF GLOBAL CHANGE

Precipitation 2100: CCSM v. MIROC



CC Impacts on Roadway Bridges

Stratus Consulting (Final, 8/12/2010)

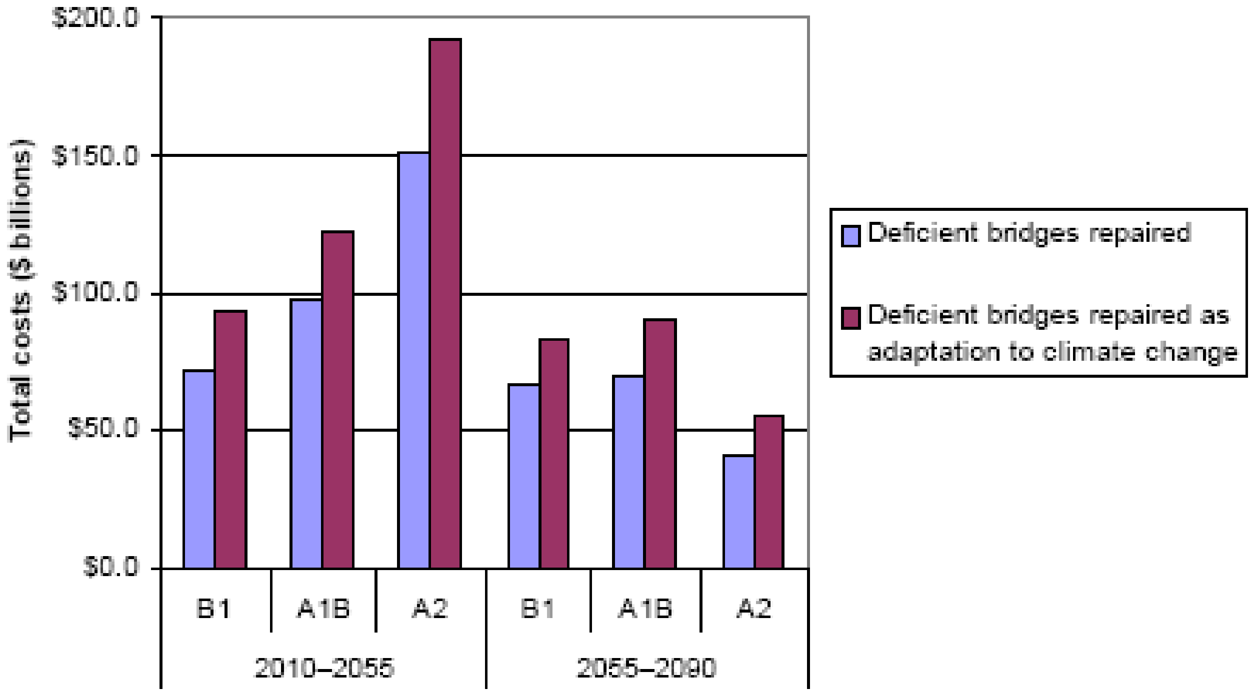
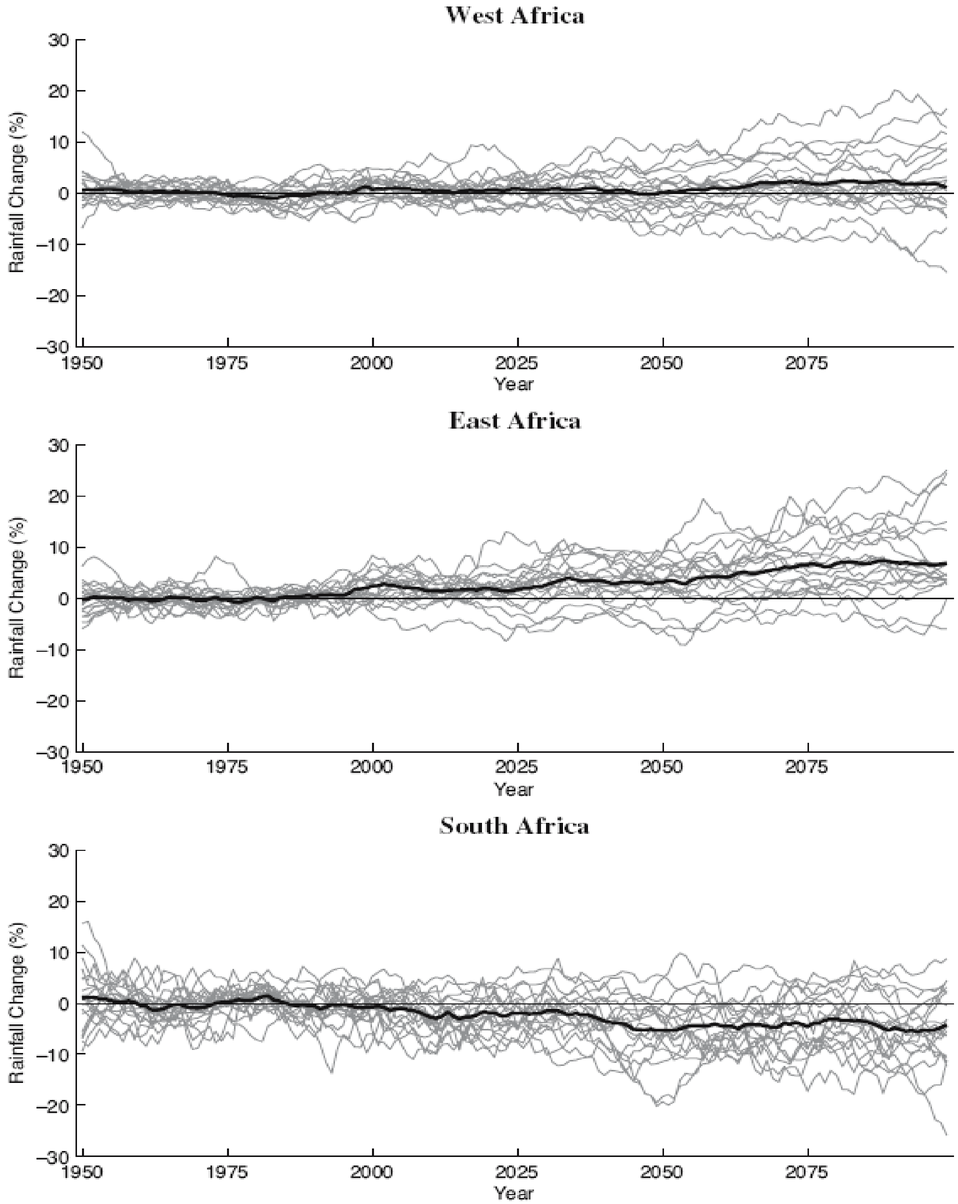


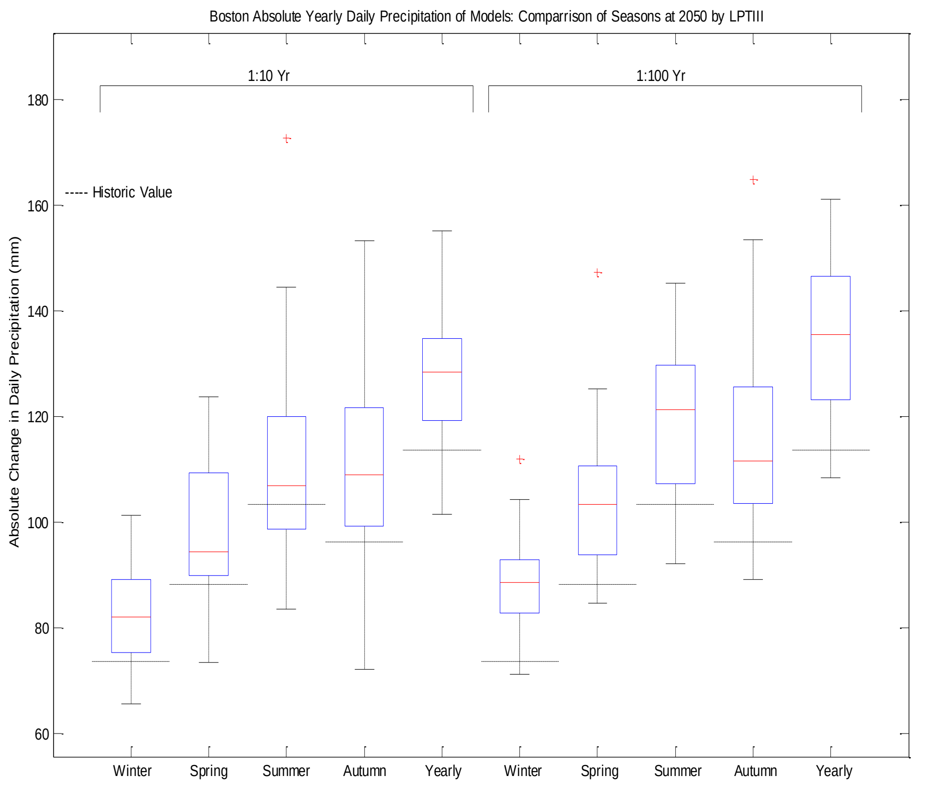
Figure 16. Costs for adapting deficient bridges to climate change by time period and scenario.

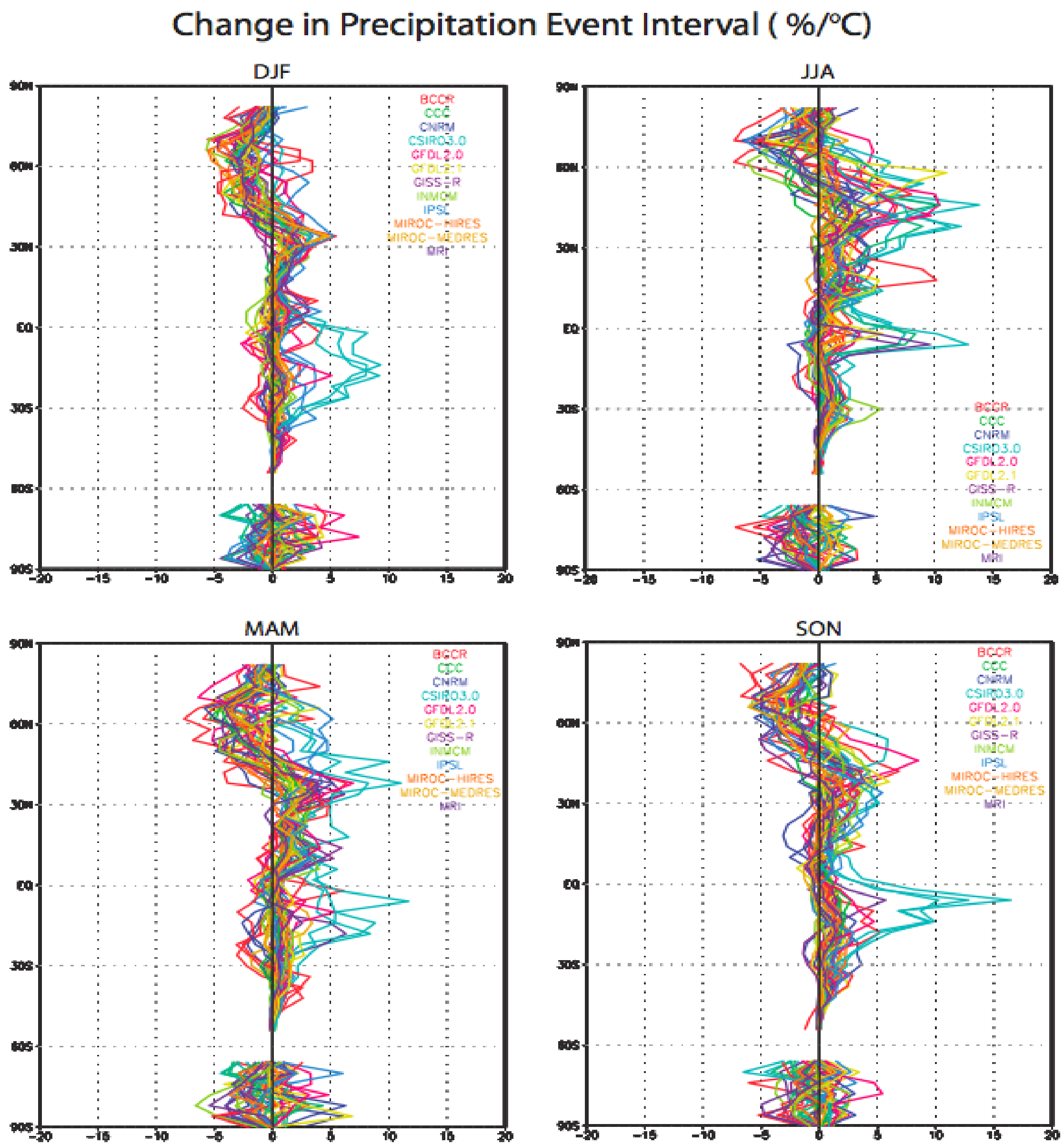
IPCC AR4 Precipitation



Boston Design Storm 2050

Current Uncertainty in 100 yr Storm much greater than range of GCM Changes





Change in Precipitation Event Interval (%/°C)
DJF
JJA
MAM
SON
BCCR
CCC
CNRM
CSIRO3.0
GFDL2.0
GFDL2.1
GISS−R
INMCM
IPSL
MIROC−HIRES
MIROC−MEDRES
MRI
90N
60N
30N
EQ
30S
60S
90S
−20
−15
−10
−5
0
5
10
15
20